AD-A136 228 LAKE DARLING FLOOD CONTROL PROJECT SOURIS RIVER NORTH DAKOTA GENERAL PROJECT DESIGN(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT JUN 83 1/7

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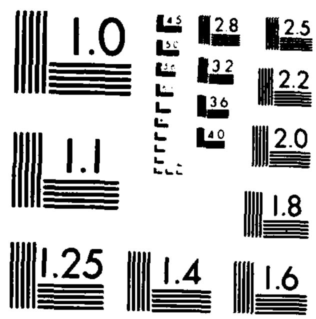

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US Army Corps of Engineers
St. Paul District

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DESIGN MEMORANDUM NO. 3
GENERAL—PROJECT DESIGN

AD-A136 228

LAKE DARLING
FLOOD CONTROL PROJECT
SOURIS RIVER, NORTH DAKOTA

JUNE 1983

UNCLASSIFIED

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Includes Appendices A, C-E. Appendix B issued separately.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

FLOOD CONTROL
SOURIS RIVER

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Lake Darling project is the second phase of the total flood control plan for the Souris Valley in North Dakota. The completed Minot channel project and the existing Lake Darling Dam provide a channel capacity of 5,000 cfs, or protection against a 15-year flood. Four floods in the last 15 years have exceeded the 5,000 cfs capacity. The Lake Darling Dam has been identified as a high hazard dam because of its location above Minot. Known problems of the structure include inadequate spillway capacity and embankment slopes.

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ST. PAUL, MINNESOTA 55101

REPLY TO
ATTENTION OF: NCSED-M 30 June 1983

SUBJECT: Flood Control, Lake Darling, Souris River, North Dakota, Design Memorandum No. 3, General-Project Design

Commander, North Central Division
ATTN: NCDED-T

1. The subject design memorandum presents designs and discussions of engineering studies for flood control improvements on the Souris River, North Dakota, and is submitted in accordance with ER 1110-2-1150.

2. I have met with local officials of counties affected by the project to discuss project sponsorship. The water resource districts of these counties have entered into an agreement to create the Souris River Joint Water Resource Board. This joint board has provided a letter of intent to accept the responsibility of serving as the local sponsor for the project. Their letter also indicates support for the project and an understanding of the traditional local cooperation requirements.

Edward G. Rapp

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as

EDWARD G. RAPP
Colonel, Corps of Engineers
Commanding

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FLOOD CONTROL

LAKE DARLING

SOURIS RIVER, NORTH DAKOTA

DESIGN MEMORANDUM INDEX

Item	DM No.	Scheduled to NCD	Submitted to NCD	Submitted OCE	Approved
Burlington Dam[1]					
Hydrology and Hydraulics	1	Feb. 1973	Feb. 1973	Apr. 1973	May 1973
Phase I GDM (Burlington Dam)	2	Dec. 1977	Dec. 1977	Feb. 1978	-
Phase II GDM (Burlington Dam)	2	Aug. 1978	Oct. 1978	Mar. 1979	Oct. 1979
Lake Darling					
General Design Memorandum	3	Jun. 1983			
Velva Improvements	4	Oct. 1982	Nov. 1982	Feb. 1983	
Highway Relocations	5	Aug. 1984			
Cultural Resources	6	Sep. 1984			
Burlington to Minot Improvements	7	Oct. 1984			
Utility Relocations	8	Nov. 1984			
Reservoir Levees	9	Jan. 1985			
Railroad Relocations	10	Apr. 1985			
Lake Darling Dam					
- Outlet, Spillway and Embankment	11	Jun. 1985			
- Concrete and Riprap Materials	12	Jun. 1985			
- Construction Procedures and Dewatering	13	Jun. 1985			
Sawyer Improvements	14	Nov. 1985			
Refuge Structures	15	Nov. 1985			
Gassman Coulee	16	Jan. 1986			
Rural Downstream Improvements	17	Feb. 1986			

(1) Listed for basic data necessary for Lake Darling project.

Department Of The Army
St. Paul District, Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, Minnesota 55101

FLOOD CONTROL
LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

DESIGN MEMORANDUM NO. 3
GENERAL PROJECT DESIGN

PERTINENT DATA

Project Authorization - 1982 Energy and Water Development Appropriations Act, Public Law 97-88, approved 4 December 1981.

Project Purpose - Flood control.

Project Location - Souris River, North Dakota.

Lake Darling Dam And Reservoir -

Drainage Area

Total	9,160
Primary contributing	3,400
Secondary contributing	4,630
Non-contributing	1,130

Controlling Elevations

Conservation pool	1596 feet msl
Reservoir design pool	1605 feet msl
Reservoir maximum pool	1609 feet msl

Reservoir Design Pool Surface Area

Conservation pool	10,800 acres
Total flooded area	14,250 acres

Real Estate Acquisition

Flowage easements

Storage

	Volume (acre-feet)
Conservation pool (elevation 1596)	99,000
Maximum drawdown (elevation 1591)	53,000
Design pool (elevation 1605)	213,000
Maximum flood control storage (elevation 1591-1605)	160,000
Existing controlled storage (elevation 1598)	121,000
Increased storage capabilities (elevation 1598-1605)	91,400

Lake Darling Dam

Existing Dam

Embankment length	3,700′
Embankment crest elevation	1606
Spillway crest elevation (service and emergency)	1598 and 1602
Spillway length (service and emergency)	320′ and 250′
Outlet works	two slide gates 12′ W x 10′ H

Modified Dam

Embankment - crest elevation	1614

Spillway — Replace with gated spillway

Number of gates	Five
Size of gates	43′ W x 22′ H
Crest elevation	1584
Crest length (net)	215′
Design discharge	99,800 cfs

Outlet Works

Type	slide gate-controlled conduits in spillway piers
Number of conduits	four
Conduit size	3′ W x 4′ H
Design discharge	1200 cfs

Relocation Features In Reservoir

State Highway 5	raise to el. 1607.5
State Highway 28	raise to el. 1607.0

Grano Crossing (FAS 3828)	raise to el. 1607.0
Lake Darling Dam Crossing	provide bridge over spillway
Other roads	misc. stabilization
Soo Line Railroad	raise to el. 1608.0 (top of rail)
Utilities (electricity gas, telephone, water)	13.7 miles to be constructed

Levee And Channel Modification

Burlington to Minot

Design capacity	5,000 cfs
Total length of levees	5.4 miles
Channel modifications	2.0 miles

Sawyer

Design capacity	5,500 cfs
Total length of levees	0.8 mile

Velva

Design capacity	14,700 cfs
Total length of levees	1.9 miles
Channel modifications	0.9 mile
Channel cutoff	0.5 mile
Channel-barrier structures	two
Channel-control structure	one

Interior Drainage In Local Protection Areas

Upstream of Lake Darling Dam

Gated gravity outlets	three
Permanent pumping stations	one
Portable pumping facilities	two

Minot to Burlington

Gated gravity outlets	seven
Pumping stations	six
Intercepting storm sewer	1,565 feet

Sawyer

Gated gravity outlet	one

Velva

Gated gravity outlet	seven
Pumping stations	one
Intercepting storm sewer (new)	3,870 feet

Rural Measures	Flood proof 113 residences downstream from dam

Project Economics

Total first costs	\$68,132,000
Total average annual costs	\$ 4,183,200
Total average annual benefits	\$ 5,459,700
Benefit-cost ratio	1.31

FLOOD CONTROL
LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

DESIGN MEMORANDUM NO. 3
GENERAL PROJECT DESIGN

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INTRODUCTION

1. The Lake Darling project is the second phase of the total flood control plan for the Souris Valley in North Dakota. The channel modification in Minot, which was authorized in 1970 and completed in 1979, was the first phase of construction. In 1970, the Burlington Dam project was authorized as the second phase of the flood control plan; however, because of the controversial nature of that project, a scaled down version was pursued by local interests. The resulting action was the authorization in the 1982 Energy and Water Development Appropriations Act of 4 December 1981 (Section III of Public Law 97-88), to raise the dam at Lake Darling by approximately 4 feet and to implement upstream and downstream flood control measures. In addition, the Senate appropriations committee, in Report No. 97-256, 28 October 1981, directed that the Corps of Engineers should take no further action to construct the Burlington Dam until expressly directed to do so by the committee. Some features of the presently authorzed project were also included in the Burlington Dam plan; however, the Burlington Dam and Des Lacs River Diversion improvements have now been placed in a deferred status. The Burlington Dam project, funded to begin preconstruction planning with FY 1972 appropriations, was awaiting approval of postauthorization changes at the time the current project was authorized. Preconstruction planning had been completed. A phase I general design memorandum was completed in December 1977 and a phase II general design memorandum was completed in August 1978. A draft environmental impact statement (EIS) was completed in September 1977, and the final EIS was completed in December 1977. A draft supplement to the EIS addressing the Endangered Species Act of 1973 and Section 404 of the Clean Water Act was distributed for public review in December 1979.

2. The completed Minot channel project and the existing Lake Darling Dam provide a channel capacity of 5,000 cfs, or protection against a 15-year flood. The relationship of the dam to the channel project cannot be overemphasized. Four floods in the last 15 years have exceeded the 5,000 cfs capacity of the channel. The channel project includes several miles of levees which could be overtopped and cause extensive damages and possible loss of life.

3. The Lake Darling Dam structure has been identified as a high hazard dam because of its location above Minot. Known problems of the structure include inadequate spillway capacity and embankment slopes which do not meet current stability criteria. The raise of Lake Darling Dam to provide additional storage for flood control will include measures of upgrading the structure to meet all dam safety criteria.

4. In 1936, the U.S. Fish and Wildlife Service completed Lake Darling Dam, which is located on the Souris River at the Ward-Renville County Line. The existing reservoir has a capacity of 121,000 acre-feet at elevation 1598. The reservoir is used to supply water to smaller wildlife reservoirs located farther downstream on the Souris River.

5. The existing dam is an earth-fill structure about 30 feet high, with the crest at elevation 1606. It includes a 320-foot-long uncontrolled service spillway on the left abutment, a 250-foot-long emergency spillway on the right abutment, and a 2-barrel gated low-level outlet works.

6. This general design memorandum is to serve as a functional design document concerned primarily with the technical design of the structures. Because the project authorization was specific in regard to the primary flood control measure of raising the existing Lake Darling Dam, this report will only briefly reevaluate flood control alternatives that have been previously studied. Although only a basic level of design detail is presented on certain project features, those features are considered to be sufficiently independent for their designs to be formulated further in the respective feature design memorandums.

PROJECT AUTHORIZATION

7. The project for flood damage reduction on the Souris River, North Dakota, recommended by the Chief of Engineers in House Document No. 321, 91st Congress, 2d session (project document), provided for two major structural measures: channel improvement through Minot, North Dakota, and upstream reservoir development. The channel improvement feature was approved by Senate and House Public Works Committee resolutions adopted 25 June and 14 July 1970, respectively. The reservoir feature was authorized later by the Flood Control Act approved 31 December 1970 (Public Law 91-611). The Minot channel improvement was authorized separately to provide limited flood protection for the city at the earliest possible date. Work on this phase of the project was completed in 1979. At the time the current project was authorized, the reservoir feature was awaiting approval of a congressional post-authorization change. Current authorization for the scaled down reservoir project came in the fiscal year 1982 Energy and Water Development Appropriations Act, Public Law 97-88, which was signed on 4 December 1981. The authorizing language states:

> "The Chief of Engineers is hereby directed to raise the dam at Lake Darling, North Dakota, by approximately four feet and to implement upstream and downstream flood control measures."

8. The Senate Appropriations Committee provides the following

accompanying committee language in Senate Report 97-256:

> "The Committee is aware of the pressing need for additional flood control measures on the Souris River to prevent serious and recurrent flooding that affects thousands of people in Minot and the outlying areas. Flood protection planning has been in progress since 1957 and more than $25,000,000 has been spent since 1969 for emergency flood fighting activities in Minot and surrounding areas.
>
> "This implementation schedule for the project will both keep it within budget restrictions and insure significant flood control protection as quickly as possible. This phase of the Burlington Dam project has a 3.3 cost-benefit ratio.While the Committee realizes that this phase will not provide complete flood protection by itself, we feel it is a logical and cost-effective step and has the strong support of local interests.
>
> "The funds provided are to be used to raise Lake Darling by approximately 4 feet and to implement work on upstream and downstream flood control measures. This Committee directs that the Corps take no further actions to construct Burlington Dam until expressly directed to do so by the Committee.
>
> "The Committee also directs that the Corps expeditiously prepare a report on the mitigation needs related to raising Lake Darling and submit the report to Congress. It is unclear at this time whether any mitigation lands will be needed; however, we urge the Corps to carefully consider the impacts of any possible mitigation, specifically on agricultural activity and on affected landowners. An amount not to exceed $1,000,000 from available funds shall be made available for this work in fiscal 1982. Work on these necessary flood protection measures should proceed while the mitigation report is being prepared."

LOCAL COOPERATION

9. By resolution dated 19 June 1969, the Ward County Water Management Board agreed to sponsor a channel improvement project at Minot and to meet the local cooperation requirements for an overall flood protection plan. When the current project was authorized, it was recognized that there was a need for a joint board representing the counties affected by the project to serve as local sponsor. On 18 August 1982, the Ward County Water Resources District provided a letter of intent to accept the responsibilities as the lead agency of a joint organization (copy

in appendix E). The letter indicated a willingness to work in good faith with the Administration of the United States in the planning and funding process for the project. On 6 June 1983, the representatives of the water resource districts from Ward, Renville, McHenry, and Bottineau Counties and the Oak Creek drainage area agreed to become members of a Souris River Joint Board for flood control, which would serve as local sponsor for the project. The general letter of intent to serve as a local sponsor was signed by their president on 14 June 1983 (copy in appendix E).

10. Items of local cooperation now considered for the Lake Darling project include the following:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction and subsequent maintenance of the project;

b. Hold and save the United States free from damages resulting from the construction, operation, or maintenance of the project, except where such damages result from negligence by the United States or its contractors;

c. Maintain and operate all of the works for the project after completion in accordance with regulations prescribed by the Secretary of the Army;

d. Accomplish without cost to the United States all necessary changes to buildings, highway bridges (including approaches), streets, dams, sewers, and utilities required for construction of the project;

e. Prescribe and enforce regulations to prevent encroachment on downstream channel capacities for regulation of the reservoirs; and, if drainage channel capacities and ponding areas for interior drainage are impaired, provide substitute storage capacity or equivalent pumping capacity promptly without cost to the United States;

f. Inform affected interests at least annually that the project will not provide complete flood protection;

g. Provide guidance and leadership in preventing unwise future development of the flood plain by use of appropriate flood plain management techniques to reduce flood losses from the Lake Darling damsite downstream to the Canadian border;

h. Adjust all water-rights claims resulting from the construction and operation of the project, and hold and save the United States free from damages resulting from such claims;

i. Zone land currently in agricultural and/or recreational land use to continue in those uses after flood protection is provided by the project;

j. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, approved 2 January 1971, in acquiring lands, easements, and rights-of-way for construction and subsequent maintenance of the project and inform affected persons of pertinent benefits, policies, and procedures in connection with said Act;

k. Comply with Section 601 of Title VI of the Civil Rights Act of 1964 (Public Law 88-352) and Department of Defense Directive 5500.11 issued pursuant thereto and published in Part 300 of Title 32, Code of Federal Regulations, in connection with the construction and subsequent maintenance and operation of the project; and

l. Hold and save the United States free from damages in the event the levees in the area upstream of Lake Darling Dam are overtopped.

Items a, c, and d pertain only to flood protection measures downstream of the reservoir. Item i pertains only to land protected by the Velva levee feature and may not be a part of the final local cooperation agreement items for the project sponsor but will be done by the city of Velva.

LOCATION OF PROJECT AND TRIBUTARY AREA

11. The Souris River basin encompasses 24,000 square miles in southeastern Saskatchewan, southwestern Manitoba, and northwestern North Dakota (see plate 1). Of the total area, 15,000 square miles (62 percent) are in Canada and 9,000 square miles (38 percent) are in the United States.

12. The Souris River originates in Saskatchewan and flows southeast for 217 miles before entering the United States near Sherwood, North Dakota. It continues southeast, passing through Minot, Sawyer, and Velva, then flows northeast to Towner, North Dakota, where it gradually assumes a northwest heading and reenters Canada near Westhope, North Dakota. The river travels 358 miles from near Sherwood to Westhope and another 154 miles in Manitoba before emptying into the Assiniboine River, which flows into the Red River of the North at Winnipeg, Manitoba. Important tributaries of the Souris River are the Des Lacs, Wintering, and Deep Rivers, Willow Creek, and Gassman Coulee in North Dakota and Moose Mountain Creek in Saskatchewan. The Des Lacs River, with a drainage area of 1,050 square miles, enters the Souris River 7

miles upstream of Minot.

13. The Souris River, normally sluggish, meanders in an oversized valley cut when the river was swollen with glacial meltwater. The valley is broad, generally flat-floored, and incised 100 to 200 feet lower than adjacent uplands except in the flat, glacial Lake Souris area at Towner. Its width varies from one-half mile at Sherwood, to about 1 mile at Minot, to 3 miles near Towner, and averages about three-fourths mile. Downstream from where the Souris River enters the United States to its confluence with the Des Lacs River and from near Bantry and Upham, North Dakota, to the international boundary, artificial lakes for wildlife management, impounded by earth dams, cover much of the valley floor. Lake Darling is the largest, extending from the southern boundary of Renville County, North Dakota, to about 20 miles upstream at normal pool level. Below the confluence with the Des Lacs River, the Souris River winds in a steep-walled valley as far as the glacial Lake Souris area. At Minot, the south valley wall reaches about 200 feet in height and the north valley wall is about 150 feet. Many small tributary coulees are cut deep in the south valley wall. Few tributaries enter from the north because of the northeast slope of the adjacent upland. The valley reach extending north from the southwestern limit of the glacial Lake Souris area is very shallow, but downstream from Upham the valley deepens progressively to about 100 feet at the Westhope crossing of the international boundary. The river slope averages about 0.56 foot per mile, and the natural channel capacity varies from about 2,000 cfs (cubic feet per second) near Burlington, to 2,500 cfs at Velva, to less than 1,000 cfs in the Towner area.

14. The Des Lacs River rises in Canada about 2 miles north of the international boundary and flows generally southeast about 110 river miles to join the Souris River at Burlington, North Dakota. A series of interconnected, shallow, artificial lakes with levels controlled by low dikes cover the upstream 33-mile reach. Downstream from the lakes, the river meanders in a channel entrenched about 15 feet below the valley floor. The steep valley walls rise to a maximum height of about 225 feet near Donnybrook, North Dakota. From the international boundary downstream to Kenmare, North Dakota, the valley walls are smooth and have few tributary entries, but downstream from Kenmare they are indented by many small tributary coulees which enter the Des Lacs River valley from the southwest. The river slope averages about 3 feet per mile and the channel capacity at Foxholm, North Dakota, is about 1,500 cfs. Gassman Coulee drains about 40 square miles. This small stream is significant, because it joins the Souris River only 1 1/2 valley miles above Minot and has a steep gradient of about 25 feet per mile.

15. During 1935 and 1936, the U.S. Fish and Wildlife Service constructed and placed in operation three migratory waterfowl refuges in the Souris River basin, one on the Des Lacs River and two on the Souris River. The Des Lacs River project consists of a series of eight dams near Kenmare which regulate water levels in reservoirs in the upper reach of the river. The Upper Souris River project, northwest of Minot in Ward and Renville Counties, includes a series of four dams and reservoirs, created by a dam at the Ward-Renville county line. Lake Darling is one of these. Lake Darling Reservoir has a capacity of about 121,600 acre-feet at spillway crest elevation 1598 and is used primarily for supplying water to smaller impoundments downstream as needed to maintain favorable waterfowl conditions. The J. Clark Salyer project extends from Upham downstream to the international boundary and provides for ponding water behind a series of five low dams.

16. The refuges contribute significantly to waterfowl production and provide resting areas for migrating waterfowl. Their upland and wooded areas support deer and small game birds and animals. Lake Darling reservoir has a productive fishery which includes walleye, northern pike, and panfish. The U.S. Fish and Wildlife Service, in cooperation with local interests, is providing recreation facilities at the refuges.

HYDROLOGY AND HYDRAULICS

17. The hydrologic data and analysis for the Lake Darling flood control project are provided in appendix A. Flood frequency curves for natural, existing and modified conditions at various locations along the Souris River, hydrographs for several historic floods, and the probable maximum flood data are shown on plates in appendix A. There are also discussions of the design for the Lake Darling Dam spillway and outlet works, a dam break analysis, and water quality evaluation.

18. Hydraulic analyses conducted previously for Burlington Dam studies and the Minot Flood Insurance Study were updated and expanded for this design memorandum. These analyses included water surface profile computations, channel capacity studies, levee and channel improvement design for local protection features, wave analyses and associated erosion protection design, and interior flood control design for leveed areas. Detailed discussions of these hydraulic analyses and designs are presented in appendix A. The general descriptions and plan drawings of the proposed project features presented in the main portion of this report are generally only referenced in appendix A to avoid substantial duplication.

GEOLOGY AND SOILS

19. The Souris River basin lies in the Drift Prairie section of the Central Lowland Physiographic province and in the Coteau Du Missouri, which forms the eastern border of the Great Plains physiographic province. Four major geologic and topographic features further subdivide these major sections. These are the Missouri Escarpment, ground-moraine plain, the lake bed of glacial Lake Souris, and the southwest portion of the Turtle Mountain. The Souris River valley upstream from Verendrye is in the ground-moraine plain and was carved when the river was swollen with glacial meltwater. The existing condition in the valley is one of a small stream in a prominent, oversized valley. Downstream from Verendrye, the river valley is formed in the glacial Lake Souris area and is a subtle feature that in places is barely perceptible.

20. Unconsolidated surface deposits in the basin are of two types: recent alluvium and Pleistocene glacial deposits. Recent alluvium comprises only a small portion of the surface materials and consists of clay, silt, fine-to-medium sand with minor amounts of coarse sand, and gravel. Significant alluvial deposits are restricted to the valleys of the Souris and Des Lacs Rivers where they generally exceed 50 feet in thickness. The glacial material consists primarily of morainal deposits and sediments of glacial Lake Souris. Morainal deposits are composed of an impervious, stoney clay till with thin seams, lenses, and channels of sand and gravel. The deposits of glacial Lake Souris range in thickness from a feather-edge to more than 70 feet. Material in the Lake Souris area is predominantly silt and moderately-to-poor graded sand with sand and gravel beach and other near-shore deposits.

21. The bedrock units exposed or forming the buried preglacial erosional surface in the Souris River basin are, in descending order, the Sentinel Butte, Tongue River, and Cannonball Formations of the Fort Union Group of the Tertiary System and the Hell Creek and Fox Hills Formations of the Cretaceous System. Older Mesozoic and Paleozoic beds underlie these formations and consist primarily of shales, limestones, sandstones, siltstones, and evaporites having a total thickness of several thousand feet.

LAKE DARLING DAM

22. The river alluvium at Lake Darling Dam has a maximum depth of about 140 feet. The potential for large settlements precludes the placement of concrete structures in the river valley. Therefore, the combined outlet and spillway structure of the dam was placed in the left abutment where it can be founded on either the Tongue River Formation or the Glacial Till, both of which are overconsolidated and much less compressible than the river allu-

vium. The existing Lake Darling Dam will require extensive modification. The top of the dam will be raised to elevation 1614.0, and the upstream and downstream slopes will be flattened to 1V on 3.75H. The upstream slope is being flattened to meet sudden drawdown criteria. Excess material excavated from the combined control structure and associated approach and discharge channels will be used to construct a large berm on the downstream side of the dam.

LEVEE AND CHANNEL SECTIONS

23. The typical levee section has a 10-foot top width with 1V on 3H side slopes. Typical cut slopes for channels will also be 1V on 3H. Riverside levee slopes and channel cut slopes of 1V on 2.5H have been used in some areas where adequate room is a serious constraint. Channel slopes and riverside levee slopes will be protected with riprap and bedding where exposed to high velocity flow and/or wave action. In remaining areas, erosion protection will consist of 4 inches of topsoil and seeding.

EVALUATION OF PROJECT PLAN

24. Several plan formulation studies have been done for the Souris River basin. The most recent was completed in December 1977 and was presented in the Burlington Dam phase I general design memorandum (GDM) of that date. Alternatives studied ranged from doing nothing about the flood problems (no action) to using all available nonstructural and structural means of reducing flood damages in the basin. Fourteen alternatives for flood damage reduction were developed and assessed for the December 1977 phase I GDM on the basis of how they meet national objectives and the specific objectives of the study. The following is a brief description of these alternatives.(1)

PLAN 1 - NO ACTION

25. The no-action alternative was the base condition upon which the effectiveness of all other alternatives was evaluated. It involved reliance on existing floodplain management programs and no further action other than possible expansion of existing programs. These programs included flood storage provided behind Lake Darling Dam and by the Minot channel project, flood warning systems and emergency protective measures, flood insurance, and floodplain regulations. The base condition assumed that the Fish and Wildlife Service would upgrade Lake Darling Dam to meet

(1) Costs included in the discussion are expressed in October 1977 prices.

current engineering standards so that it can be reliably operated for flood control. Operation of the dam was assumed to be similar to past operation.

26. The flood storage capacity provided in Lake Darling (maximum of about 80,000 acre-feet) in conjunction with the Minot channel project, designed to pass a maximum flow of 5,000 cfs, would only protect Minot from a Souris River flood having a 6.6 percent chance of occurring during any year (15-year flood). Protection against larger floods would require reliance on flood warning and emergency protection measures. However, this would involve substantial risks, particularly at Minot where approximately 4,000 developments are subject to flooding within a short period of time.

27. Ward County, Minot, and Velva had enacted regulations restricting development in the 100-year flood plain and had made flood insurance available to occupants of the flood plain. Expansion of these regulations to prevent damageable development in the flood plain would reduce potential flood damages but would do little to reduce damages to existing developments in the flood plain. Also, the continuance of flood insurance programs would compensate the individual property owner but would not reduce flood damages on a national scale. Considered collectively, the several flood plain management techniques available under the no-action alternative would not meet the basic objective of the study by providing adequate flood damage reduction at Minot and other flood-prone areas. These areas would remain vulnerable to damages approaching $60 million from a flood similar in magnitude to the 1976 flood and to estimated average annual damages of $7.18 million. On this basis, the no-action alternative was not considered further. However, continuance of flood plain regulations, flood insurance programs, and flood warning systems was considered as a supplement to a structural plan of development.

PLAN 2 - FLOOD PLAIN EVACUATION

28. The floodplain evacuation alternative would require relocation of 3,500 permanent residences and 300 businesses in the 100-year Minot flood plain and an additional 600 residences and 50 businesses in areas of the 100-year flood plain outside Minot. Although the evacuation alternative would permit restoration of the natural environment, it was not considered a practicable solution to the flood problem because: (a) the social and political problems associated with relocation of such a large mass of people were too great; (b) the non-Federal share, $44.4 million, far exceeded the local financial capability; and (c) the plan was not economically feasible, having a total cost of $266 million and a benefit-cost ratio of 0.64. However, evacuation was consi-

current engineering standards so that it can be reliably operated for flood control. Operation of the dam was assumed to be similar to past operation.

26. The flood storage capacity provided in Lake Darling (maximum of about 80,000 acre-feet) in conjunction with the Minot channel project, designed to pass a maximum flow of 5,000 cfs, would only protect Minot from a Souris River flood having a 6.6 percent chance of occurring during any year (15-year flood). Protection against larger floods would require reliance on flood warning and emergency protection measures. However, this would involve substantial risks, particularly at Minot where approximately 4,000 developments are subject to flooding within a short period of time.

27. Ward County, Minot, and Velva had enacted regulations restricting development in the 100-year flood plain and had made flood insurance available to occupants of the flood plain. Expansion of these regulations to prevent damageable development in the flood plain would reduce potential flood damages but would do little to reduce damages to existing developments in the flood plain. Also, the continuance of flood insurance programs would compensate the individual property owner but would not reduce flood damages on a national scale. Considered collectively, the several flood plain management techniques available under the no-action alternative would not meet the basic objective of the study by providing adequate flood damage reduction at Minot and other flood-prone areas. These areas would remain vulnerable to damages approaching $60 million from a flood similar in magnitude to the 1976 flood and to estimated average annual damages of $7.18 million. On this basis, the no-action alternative was not considered further. However, continuance of flood plain regulations, flood insurance programs, and flood warning systems was considered as a supplement to a structural plan of development.

PLAN 2 - FLOOD PLAIN EVACUATION

28. The floodplain evacuation alternative would require relocation of 3,500 permanent residences and 300 businesses in the 100-year Minot flood plain and an additional 600 residences and 50 businesses in areas of the 100-year flood plain outside Minot. Although the evacuation alternative would permit restoration of the natural environment, it was not considered a practicable solution to the flood problem because: (a) the social and political problems associated with relocation of such a large mass of people were too great; (b) the non-Federal share, $44.4 million, far exceeded the local financial capability; and (c) the plan was not economically feasible, having a total cost of $266 million and a benefit-cost ratio of 0.64. However, evacuation was consi-

dered to be one of the limited practical methods of reducing flood damages in sparsely developed rural areas where structural measures are not feasible.

PLAN 3 - SOURIS RIVER DIVERSION

29. Plan 3 involved a 46-mile-long diversion channel from the upper Souris River to the lower Souris River, paralleling the international boundary, to divert flood flows in excess of channel capacity in Minot. The design capacity of the diversion channel investigated was 9,000 cfs which, when considered with the 5,000-cfs channel capacity in Minot and potential flows from the Des Lacs River, Gassman Coulee, and other drainage areas around Minot, would give the city about 70-year flood protection. Both gravity flow and pumped flow schemes were investigated. Both were found to lack economic feasibility by a wide margin based on total costs in excess of $250 million and a benefit-cost ratio of 0.3-0.4. In addition, major diversion channel plans were dismissed because of the adverse impacts the increased flows would have on lands along the lower Souris River, both in the J. Clark Salyer Refuge and in Manitoba.

PLAN 4 - FLOOD BARRIERS

30. Plan 4 involved upgrading existing emergency levees in seven urban areas between Burlington and Minot and at Minot, Sawyer, and Velva to pass a design flow of 14,000 cfs at Minot. Plan 4 would be economically feasible to implement with total costs of $68.3 million and a benefit-cost ratio of 1.41. The plan would protect Minot from about 70 percent of the Des Lacs River standard project flood, estimated at 20,000 cfs, and would provide complete protection from a local drainage area standard project flood, estimated at 11,400 cfs. In addition, plan 4 would be less environmentally disruptive than plans involving reservoir storage. However, floods in excess of 14,000 cfs could cause millions of dollars worth of damages and possible loss of life, particularly along the 13-mile-long levee system required in Minot. Also, local interests would be required to contribute an estimated $29.8 million for lands and rights-of-way and bridge and utility alterations, $28.0 million coming from Minot. The city has indicated that such a cost greatly exceeds its financial capability. Because of the increased risks to life and property from the low degree of protection and the unaffordable local costs, plan 4 was not considered further.

PLAN 5 - MINOT DIVERSION TUNNEL

31. Plan 5 had the same features as plan 4 except the levee upgrading feature at Minot would be replaced with an underground tunnel. The 2 1/2-mile-long, 41-foot-diameter tunnel would have a design flow capacity of 9,000 cfs which, in combination with

the 5,000 cfs channel, would protect Minot from a total flow of 14,000 cfs (similar to plan 4). To reduce high stages in Minot and eliminate the need for levee extensions within the city, approximately 27 miles of widening and straightening of the Souris River channel would be required below the tunnel outlet near the downstream city limits. Plan 5 had an estimated total cost of $90.49 million and a marginally feasible benefit-cost ratio of 1.0. Like plan 4, plan 5 would provide a high degree of protection from the Des Lacs River and the local drainage area, but a relatively low degree of protection from the Souris River. However, because of the environmental attributes of an underground tunnel and the relatively low local costs as compared to an all-levee plan, plan 5 was retained as a basis for developing the environmental quality (EQ) plan.

PLAN 6 - BURLINGTON DAM

32. Plan 6 involved a dam on the Souris River about 1 mile upstream from the site recommended in the authorizing document. Total flood storage capacity would be 63,000 acre-feet to elevation 1620, which is approximately 3 feet below the valley bottom elevation at the international boundary. Plan 6 also involved a 4-foot raise of the existing Lake Darling Dam, fish and wildlife mitigation measures, upgrading levees in the nine urban areas between Burlington and Minot and at Sawyer and Velva, and a combination of structural and nonstructural measures for approximately 117 rural dwellings between Burlington and the J. Clark Salyer Refuge. All of the features below the dam would be designed to safely pass the 5,000-cfs design flow from the dam plus local inflow below the dam. Lake Darling Dam would control all floods up to the estimated 50-year flood level. Burlington Dam would be used only to temporarily store floods in excess of the 50-year flood and would have no conservation pool. The storage capacity afforded under plan 6 would control approximately 80 percent of the Souris River standard project flood using the proposed plan of operation. No further control would be provided over floods from the Des Lacs River or from the drainage area around Minot. Thus, recognizing the probability of flows from all three sources exceeding 5,000 cfs at Minot as independent events, plan 6 would provide the city with about 130-year flood protection.

33. This plan would cause significant social and environmental losses, including: the purchase of 14,000 acres of farmlands; the dislocation of 30 farm and nonfarm families; the purchase of Renville County Park; protective measures for McKinney Cemetery; and the periodic inundation of 14,470 acres of forest, grass, marsh, and croplands. However, with total costs of $77.3 million and a benefit-cost ratio of 1.62, plan 6 was more cost effective and would provide a more reliable degree of protection from the Souris River, the principal flood source, than other alternatives considered.

PLAN 7 - LAKE DARLING DAM

34. Plan 7 involved a raise of the existing Lake Darling Dam, providing a total flood storage capacity of 383,000 acre-feet to elevation 1620, and features between Burlington and the J. Clark Salyer Refuge similar to plan 6. Also, because of the negligible contributing drainage area between Burlington and Lake Darling Dam, there would be no change in the reservoir plan of operation. Adverse social and environmental impacts included the purchase of some 7,000 acres of farmland; dislocation of 21 farm and nonfarm families; purchase of Renville County Park; protective measures for McKinney Cemetery; and periodic inundation of some 8,150 acres of forest, grass, marsh, and croplands. The added storage capacity afforded under plan 7 would control approximately 60 percent of the Souris River standard project flood at full design pool and a maximum release rate of 5,000 cfs. No further control would be provided for floods from the Des Lacs River or from the drainage area around Minot. Recognizing the probability of flow from all three sources exceeding 5,000 cfs at Minot as independent events, plan 6 would provide the city with combined 105-year flood protection. In addition to providing a substantial degree of Souris River protection, plan 7 is the most economical of the 14 plans, having total costs of $57.03 million and a benefit-cost ratio of 2.16. Accordingly, plan 7 was considered the basis for the national economic development (NED) plan.

PLAN 8 - CONFLUENCE DAM

35. Plan 8 involved a dam on the Souris River just below its confluence with the Des Lacs River. This plan included the same reservoir operation and downstream features as plan 6, but would involve additional social and environmental impacts. These included purchase of approximately 3,300 acres of farmlands; dislocation of 50 families; purchase of Old Settlers Park; relocation of Burlington Cemetery and grade school, and periodic inundation of 3,280 acres of forest, marsh, and croplands. High-cost features of plan 8 include the relocation of about 7 miles of track line of the Soo Line Railroad and 4 miles of U.S. Highway 52. The confluence dam would control 80 percent of the Souris River standard project flood and completely control Des Lacs River floods. No further control over local drainage area floods would be provided to Minot. Recognizing the probability of floods exceeding 5,000 cfs from any one of three sources acting independently, this plan would provide combined 280-year flood protection at Minot. Of the 14 plans considered, plan 8 would afford the best degree of control over Souris and Des Lacs River floods, and with total costs estimated at $106.87 million and a benefit-cost ratio of 1.22, would be economically feasible to implement. However, because of the additional adverse social and

environmental impacts in the Des Lacs River Valley and the relatively high total costs, plan 8 was not selected.

PLAN 9 - BURLINGTON DAM AND DAMS ON DES LACS RIVER TRIBUTARIES

36. Plan 9 involved the Burlington Dam as discussed under plan 6 in combination with dams on 19 coulees tributary to the Des Lacs River. These coulees have extremely steep gradients. Accordingly, dams over 100 feet high would be required to control the contributing drainage area, which amounts to only about 20 percent of the total drainage area of the Des Lacs River. The total cost of plan 9 was $171.95 million and the benefit-cost ratio was 0.74, making it economically infeasible. Because better control over Des Lacs River floods could be economically attained with other alternatives, plan 9 was not considered further.

PLAN 10 - BURLINGTON DAM AND DES LACS RIVER DIVERSION TUNNEL

37. Plan 10 had all of the features of plan 5 plus a diversion tunnel to control Des Lacs River flood flows in excess of the 5,000 cfs channel capacity at Minot. The inlet of the diversion tunnel would be located about 1 1/2 miles below Foxholm. Des Lacs River flows up to 4,500 cfs would be diverted through a 1-mile-long, 22-foot-diameter, concrete lined tunnel into the reservoir storage area of the Souris River Valley created by the Burlington Dam. This plan would control approximately 80 percent of the Souris River standard project flood and about 70 percent of the Des Lacs River standard project flood. No further control would be afforded Minot from the approximately 106 square mile drainage area around the city. In terms of frequency, plan 10 would provide Minot with combined 240-year flood protection, recognizing the probability of flows exceeding 5,000 cfs from any source acting independently. The adverse social and environmental impacts of the tunnel are minimal. Plan 10 is economically feasible, having total costs of $92.6 million and a benefit-cost ratio of 1.39. For these reasons, plan 10 was the selected plan.

PLAN 11 - LAKE DARLING DAM AND DES LACS DIVERSION TUNNEL

38. Plan 11 involved the same features as plan 7 plus a tunnel to divert Des Lacs River flows in excess of the channel capacity at Minot to Lake Darling. This tunnel would be the same as the one in plan 10, except that the inlet would be located 10 miles above Foxholm. To minimize costs, the tunnel length would be increased to 4 miles and the tunnel diameter would be increased to an average of 25 feet. Plan 11 would provide Minot with combined 170-year flood protection and would be economically feasible to implement, with total costs of $107 million and a benefit-cost ratio of 1.2. However, this plan would provide less

control over Des Lacs River floods and would be less cost effective than plan 10. For these reasons, plan 11 was not considered further.

PLAN 12 - BURLINGTON DAM, DES LACS RIVER DIVERSION TUNNEL, GASSMAN COULEE DAM

39. Plan 12 involved all of the features of plan 10 plus a dam on Gassman Coulee, sized to control all floods up to the standard project flood from the coulee's 40-square-mile drainage area. At full design pool elevation, the 100-foot-high-dam would create about 11,000 acre-feet of storage over about 370 acres of grass and wooded lands. Addition of a dam on Gassman Coulee would eliminate the threat of severe damages and loss of life from extreme floods and would increase the combined degree of protection at Minot to once in 1,100 years, recognizing the probability of flows exceeding 5,000 cfs from all sources as independent events. Considered in totality, plan 12 was economically feasible with total costs of $111.88 million and a benefit-cost ratio of 1.18. However, incrementally, a dam on Gassman Coulee lacks feasibility by a wide margin because the coulee has only a once in 300-year chance of producing flows in excess of 5,000 cfs. Also, a dam on Gassman Coulee would not significantly reduce residual flows at Minot from a standard project flood from the total drainage area around the city. Accordingly, plan 12 was not considered further.

PLAN 13 - LAKE DARLING DAM AND MINOT DIVERSION TUNNEL

40. Plan 13 had all of the features of plan 7 plus a tunnel under Minot to divert 5,000 cfs. Combined with the 5,000 cfs channel, this would provide a flood-free capacity of 10,000 cfs. Conceptually, the tunnel would be similar to the 9,000 cfs tunnel in plan 5 except that its diameter would be reduced to 26 feet and a lesser amount of channel widening would be required below Minot. Also, the levees would be upgraded to pass 10,000 cfs between Burlington and Minot and 13,000 cfs at Sawyer and Velva, recognizing local inflow contributions. Assuming that Lake Darling could be operated to pass a maximum of 10,000 cfs at elevation 1620, plan 13 would provide control over about 80 percent of the Souris River standard project flood, 50 percent of the Des Lacs River standard project flood, and 90 percent of the local drainage area standard project flood. In terms of frequency, plan 13 would provide combined 520-year flood protection and was economically feasible, with total costs of $110.23 million and a benefit-cost ratio of 1.22. However, plan 13 was not considered further because of the impracticality of releasing flows up to 10,000 cfs in unprotected rural areas below Minot and because it was not as economical as other alternatives.

PLAN 14 - LAKE DARLING DAM AND FLOOD BARRIERS

41. Plan 14 would involve raising the existing Lake Darling Dam as discussed under plan 7. Also, levees would be upgraded to pass a flow of 11,000 cfs in the Burlington to Minot and Minot reaches and 14,000 cfs at Sawyer and Velva, recognizing local inflow below Minot. The levee upgrading would be similar in concept to that described under plan 4. The degree of protection afforded by plan 14 would also be similar to that of plan 13, except that the tunnel at Minot would be replaced with a levee system designed for 11,000 cfs instead of 10,000 cfs. Like plan 13, this plan would provide a high degree of flood control, particularly over the Des Lacs River and the local drainage area. Plan 14 was more cost effective, based on total costs of $102.1 million and a benefit-cost ratio of 1.32. However, the high local costs (totaling an estimated $22.0 million), the adverse impacts in unprotected areas of the assumed maximum reservoir release rate of 11,000 cfs at Minot, and the need to dislocate 250 residences in Minot were reasons for not considering plan 14 further.

42. The Lake Darling flood control plan, including a 4-foot raise as currently authorized, was not among those previously studied, although all the features of this plan were included in the recommended Burlington Dam alternative (plan 10). The primary revisions of the Burlington Dam plan are as follows:

a. Deletion of Burlington Dam structure.

b. Deletion of Des Lacs River diversion structure.

c. Increased spillway capacity required at Lake Darling Dam to prevent overtopping.

43. The features that are included in the current plan were considered by local interests to be the least controversial features of the Burlington project, and they would provide added interim flood protection until a higher degree of protection could be provided. Although recognizing the relatively slight increase in flood protection provided by a 4-foot raise of Lake Darling Dam and the reduction of incremental benefits available for a future project to provide a higher level of protection, the separate authorization of the Lake Darling project was pursued. The controversial aspects of the Burlington Dam project, such as land acquisition for the reservoir, fish and wildlife mitigation needs, and institutional impacts in the reservoir area, had caused a delay in providing flood protection and an attitude of growing dissension among Souris Valley residents. The authorization for the scaled-down reservoir project was contained in the 1982 Appropriations Act, with specific language on the construction of the primary flood control feature (approxi-

mate 4-foot raise of the existing Lake Darling Dam) and relatively open direction on other flood control measures upstream and downstream of the dam.

44. Because the authorizing language provides specific direction for the Corps to raise the Lake Darling Dam, this report will not address alternatives to the primary means of flood control. However, there was a need to further define the intent of the authorization, and an issue-resolution conference was held with personnel from the St. Paul District, North Central Division, and Office of the Chief of Engineers on 13 April 1982. A memorandum for record of that meeting (8 June 1982) is provided in appendix E.

45. The 4-foot raise is defined as similar to the Lake Darling Dam raise which was included as a part of the Burlington Dam project. The design pool level for the raised Lake Darling Dam, when included with the Burlington Dam project, was 1605, with the top of the spillway gate at elevation 1605.5. It is viewed that the authorizing language intends that a similar structure in terms of design pool level and operating plan for flood control should be provided. This is especially apparent in the accompanying appropriations committee language which refers to the current project as a "phase of the Burlington Dam project." Therefore, a structure that would provide flood control design pool storage to elevation 1605 is viewed to be a constraining design condition. Replacing the existing ungated spillway at a crest elevation of 1598.0 with another ungated spillway 4 feet higher is not practical because such a spillway would have to be 1,540 feet long (40 percent of the total valley width) to meet current design criteria of passing the probable maximum flood flows at existing headwater elevations. Therefore, the ungated spillway will be replaced with a gated structure. The current design pool in the Lake Darling reservoir is considered to be elevation 1601, which includes 3 feet of natural surcharge storage over the fixed spillway crest. A 4-foot raise, therefore, would result in a new design pool level of 1605, including surcharge storage. Because design criteria require that the top of the spillway gates be at least 1 foot above the design pool in a closed position, the top of the gates is considered to be at least 1606.0.

46. The gated spillway, therefore, has the capability to hold water to elevation 1605, which is an increase of 7 feet over the crest of the existing ungated spillway. The 3 feet of surcharge storage now can potentially be stored for a longer period of time than was possible with the ungated spillway, which only treated 3 feet as natural surcharge storage. The operating plan, however, as agreed upon with local interests and the U.S. Fish and Wildlife Service, would release 5,000 cfs until the reservoir reaches elevation 1600. Therefore, although the structure has the capability to store water for an extended period at elevation 1605,

the operating plan does not include provisions for extended storage above elevation 1600.

47. The accepted definition of the 4-foot raise of Lake Darling Dam, as discussed with local interests and the Fish and Wildlife Service, is to provide a gated spillway with a design pool level at elevation 1605. The maximum pool level is not to exceed the existing condition probable maximum flood level. This stage was determined by routing the probable maximum flood of 99,800 cfs through Lake Darling Dam for both a failure and nonfailure condition. The stages upstream of Lake Darling Dam for the two conditions are 1608 and 1609, respectively. Therefore, the spillway is to be designed so that the maximum pool level will not exceed elevation 1609. The 1605 elevation, however, would not be exceeded for at least a 500-year flood, or approximately a 30,000 cfs peak discharge.

48. The definition of the upstream flood control measures are considered to be the reservoir storage itself and those existing facilities that require modification as a result of reservoir storage, including the highway and railroad crossings, Renville County Park, McKinney Cemetery, farmsteads, private land, refuge facilities, and several recreation facilities. Because local interests view fee title acquisition of private land and relocation of the Renville County Park or McKinney Cemetery as unacceptable means of compensation for adverse affects of reservoir storage at higher levels, alternative measures were to be pursued at costs equal to or less than the fee title acquisition value. Further discussion of each of the above features is provided in other sections of this report.

49. The need for downstream flood control measures was recognized during the Burlington Dam project formulation. The planned reservoir release rate of 5,000 cfs is similar for both project plans; therefore, the downstream flood control features are viewed to be similar to those proposed in the Burlington Dam project.

50. The downstream urban flood protection measures, which are not incrementally justified, are to be considered as an integral part of the Lake Darling Dam structure and, therefore, can be Federally funded up to the 5,000 cfs level of protection. All downstream flood protection measures are to be accomplished with local cooperation. This means the local sponsor will be responsible for acquiring lands, easements, and right-of-way and for operating and maintaining the project. This coincides with the policy set out in a letter from the Director of Civil Works, dated 9 March 1982. The Federal Government, however, is responsible for lands and relocations in the reservoir. If the local interests desire a level of flood protection higher than the 5,000 cfs reservoir release rate provides, they would have to

fund the incremental higher level of protection themselves. Where downstream urban levees are incrementally justified, the appropriate level of protection would be that at which maximun net benefits are achieved.

51. There are essentially three basic options for the 113 downstream rural residences affected by the 5,000 cfs release: levees, flood proofing, or evacuation. In all cases, the local sponsor would be responsible for acquiring the necessary land. The most feasible solution for providing protection from the 5,000 cfs discharge will be federally funded. Local interests will be responsible for the usual local cooperation requirements, subject to the Constitution, which requires just compensation. If more expensive options are desired by either the affected homeowners or the local sponsor, additional funding may be required from the local sponsor.

52. Unless it can be shown that there are net adverse impacts from the reservoir operations on any individual ownership within the 5,000 cfs flooded area, there does not appear to be a liability on the part of the government to acquire an interest in that property. A flowage easement on the affected property would be acquired if adverse impacts are determined.

ALTERNATIVE PLANS FOR PROJECT FEATURES INVESTIGATED

OPERATING PLAN

53. The operating plan developed and coordinated for the Burlington Dam project provided for a maximum reservoir release rate of 5,000 cfs until 15 May, at which time releases would be cut back to 500 cfs. Flows could have been increaed to 700 cfs on 1 September, if necessary, to evacuate the reservoir for the following spring runoff.

54. The scaled-down reservoir project under the current authorization presented several concerns relative to the previously coordinated operating plan. The frequency at which the 5,000 cfs discharge at Minot would be exceeded would increase significantly with the Lake Darling project (once in 25 years compared to once in 240 years for the Burlington project). Therefore, a more refined plan was needed for floods exceeding the design frequency of the reservoir. Also, the small reservoir capacity could not accommodate a release cutback to 500 cfs on 15 May for even small floods that had approximately a 25-year frequency of occurring. Instead, the cutback could only be to the inflow rate, which exceeded 2,000 cfs on 15 May for some of the historic flood conditions being studied.

55. Three primary operating plans were evaluated and presented

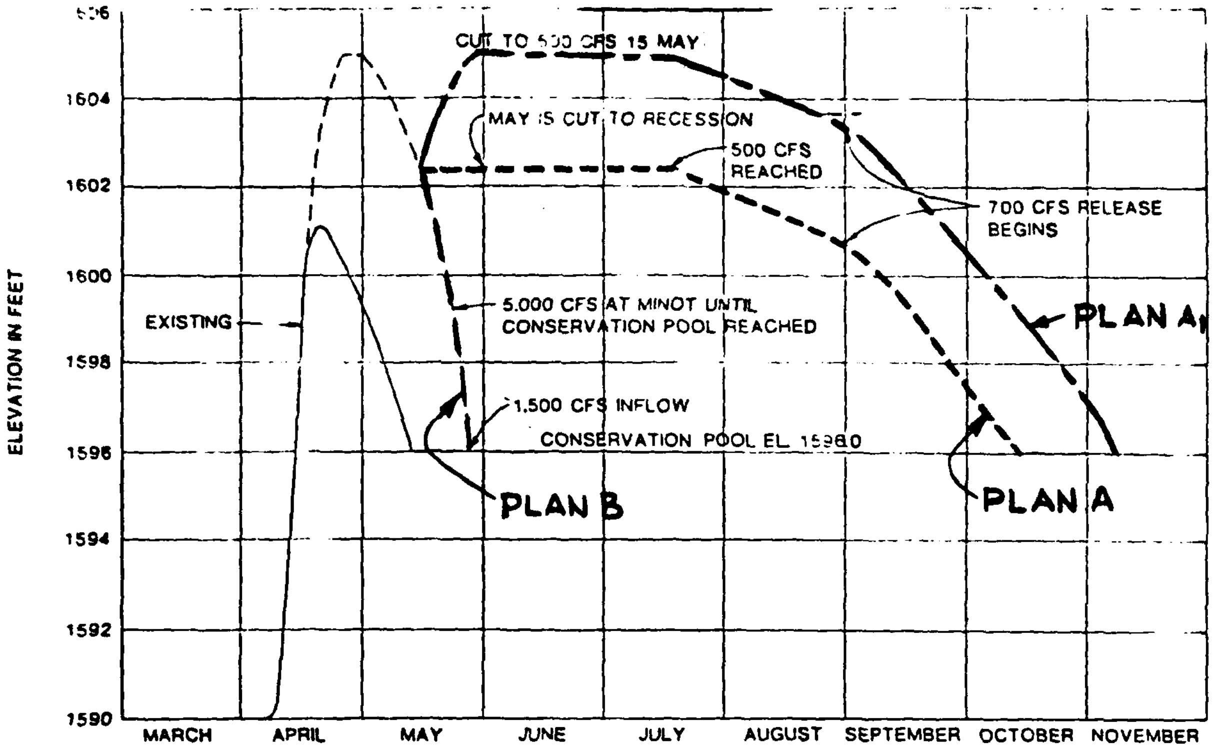
to local interests and the Fish and Wildlife Service for consideration. Stage and discharge hydrographs for a 50-year synthetic flood are provided on exhibit 1 to display these three plans.

56. Plan A1, which most resembled the Burlington Dam operating plan (5,000 cfs release until 15 May, at which time releases would be cut back to 500 cfs) was dropped early in the analysis. As seen in exhibit 1, the release rate of 500 cfs could be maintained for less than two weeks before the reservoir rose to the design pool level of elevation 1605 and releases had to be increased to the inflow rate of approximately 1,400 cfs. With even smaller floods, a cutback to 500 cfs on 15 May exhausted the available reservoir storage and resulted in increased discharges. The secondary increase in discharges would cause a significant impact on downstream agricultural lands. Also, the plan required reservoir storage for long durations at or near the design pool elevation, which was considered unacceptable by local interests and which would reduce the capability to store any summer rainfall inflows. Therefore, this plan was modified to cut back to the natural recession or 500 cfs, whichever is less. This modified plan is referred to as Plan A.

57. Plans A and B were studied in more detail. A summary of various reaches of the Souris Valley together with a perceived understanding of the preferred operating plan for each reach is shown on exhibit 2. The data on this exhibit were furnished to local representatives and to the Fish and Wildlife Service and were discussed at several meetings in the Souris Valley. Plan A was viewed as a slow release plan, while plan B was considered to be a fast release plan, releasing 5,000 cfs until the conservation pool was reached.

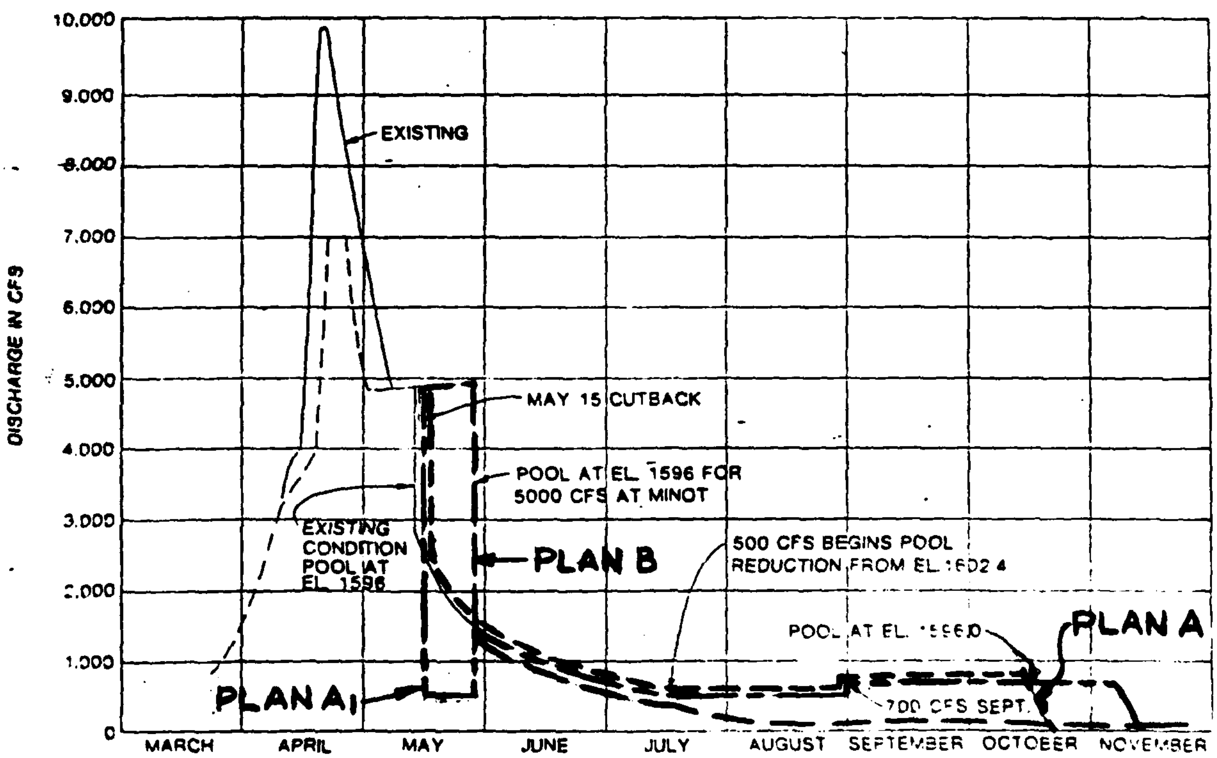
58. As shown in exhibit 2, the preference for either of the operating plans varies throughout the Souris Valley. Neither plan was most favored by the majority of the local interests. Plan A was favored when considering the economic, social, safety, and Canadian mitigation factors. However, plan B was favored from the viewpoints of hydrologic operation, engineering, environmental, and fish and wildlife mitigation factors. The Fish and Wildlife Service favored plan B, as explained in their letter of 13 January 1983 (copy provided in appendix E).

59. The St. Paul District, Corps of Engineers, recommended plan A; however, because there was also strong justification for plan B, either plan was considered acceptable. A meeting was held on 15 January 1983 with representatives of the counties that were expected to be members of the Souris River joint board for flood control, which was then being organized as the local sponsor. The decision document (in appendix E), signed by the county representatives at the meeting, recommended plan A with the provision that the 5,000 cfs release rate should continue past 15



RESERVOIR STAGE HYDROGRAPH

SOURIS RIVER-LAKE DARLING
50 YEAR FLOOD



DISCHARGE HYDROGRAPH
(FOXHOLM GAGE)

EXHIBIT 1

LANDS AFFECTED BY LAKE DARLING OPERATING PLAN

	Reach	Approx. No. of Ownership	Approx. No. of Residences	Total(2) Private Acres	Hay Acres	Crop Acres	Channel Capacity	Plan Favored? Reasons
1.	Reservoir - 1605	3(1)	0	800	0	600	-	Plan B - Water quality, erosion, 100± acres of woodlands below 1602, bridges, 2,450 acres adversely affected by prolonged storage.
	- 1602	0±	0	0±	0	0	-	
2.	USNWR (below Lake Darling) @ 5,000 cfs	FWS	0	-		-	-	Plan B - Prolonged 5,000 cfs by 2 wks has little effect, 500 cfs summer flows reduces management capabilities.
	@ 500 cfs		0			-	-	
3.	Refuge - Burlington @5,000cfs	20	4	1,700	250	800	2,000	Plan A - 800 acres of crop land drained approx. 1 wk. earlier, 500 cfs no effect
	@ 500cfs	-	0	0	0	0		
4.	Burlington - Velva @5,000cfs	95	62	6,900	650	2,300	2,500	Plan A - 2,300 acres of cropland drained approx. 1-2 wks earlier, 500 cfs has no effect, summer rainfall up to 2,000 has minimal effect.
	@ 500cfs	-	0	0	0			
5.	Velva - Verendrye @5,000cfs	11	8	1,900	100	700	1,500	Plan A - 700 acres of cropland drained sooner, 500 cfs has no effect; however cut only to recession & potential for summer rainfall high flows could be a factor.
	@ 500cfs	-	0	0	0	0		
6.	Verencrye - Wintering River @5,000cfs	25	18	4,400	500	1,600	1,000	Plan A?-940 acres of this cropland is above 2,800 cfs flooded area. Earlier drainage of these acres may offset cut only to recession & potential for summer rainfall high flows.
	@ 500cfs	-	0	0	0	0		
7.	Wintering River - Towner @5,000cfs	26	15	13,500	2,200	1,500	500	Plan B?-Only 300 acres of this cropland is above 2,800 cfs flooded area. Potential for high flows due to summer rainfall & inability to draw down to 500 cfs on May 15 may govern.
	@ 500cfs	-	0	0	0	0		
8.	Towner - Refuge @5,000cfs	26	10	7,500	3,000	100	100	Plan B - 500 cfs prevents harvest on 1800 acres haylands every 5-10 years, prolonged 5,000cfs by 2 wks has little effect.
	@ 500cfs	13	0	2,000	1,800	0		
9.	JCSNWR @5,000cfs	FWS		-	-	-	100	Plan B - 500 cfs reduces management capabilities, inundates haylands, trails and adversely affects vegetation.
	@ 500cfs		0	-	-	-	-	
	Canada @5,000cfs	Canada	-	14,400	9,400	5,000	100	Plan A?-2 cities (Melita @3,000 cfs & Souris @4,000 cfs and 5,000 cropland acres are affected by prolonged 5,000 cfs discharges). However, late floods may have already prevented any seeding on many of these acres under existing conditions.
	@ 500cfs		0	300	300	0		

PLAN A - 5,000 cfs with cutback to recession or 500 cfs on 15 May.

PLAN B - 5,000 cfs continuously until conservation pool is reached (fast release plan).

(1) Not including break-out points

(2) Easements required on any land shown to be adversely affected. Of the 37,900 acres flooded by 5,000 cfs releases, 4,000 are haylands, 7,000 are croplands, 5,000 are woodlands, 15,000 are wetlands and 6,900 are shrubs & native prairie.

Other Factors

- Costs for fish and wildlife mitigation, woodland mitigation, modification of JCSNWR structures, & carp control should be less for Plan B
- Costs for downstream flowage easements and Canadian mitigation should be less for Plan A.
- Downstream roads, bridges and improvements would be least affected by Plan A.
- Downstream channel erosion may be an adverse factor with prolonged 500 cfs flows (Favors Plan B)

Exhibit 2

May if the reservoir had not fallen to elevation 1,600. Also, it was understood that the date for reducing discharges (15 May) was to be approximate and not rigidly fixed and that the Corps should further evaluate a discharge higher than 500 cfs for a short period following 15 May to reduce the duration of 500 cfs flows.

60. Following the 15 January 1983 meeting, the modified plan was evaluated as recommended by the local interests. Also, various discharges ranging from 1,000 cfs to 2,500 cfs between 15 May and 1 June were investigated as an alternative to a 500 cfs discharge beginning 15 May. Releasing 2,500 cfs for a period in early spring could reduce the duration of the 500 cfs release approximately by a factor of 5 in the summer months. Releases of 500 cfs into the midsummer months would have significant impact on privately-owned haylands near Towner and haylands in the J. Clark Salyer Refuge that are leased to private interests. Also, the prolonged 500 cfs release would have serious effects on the management capabilities in the J. Clark Salyer Refuge. A meeting was held with the McHenry County Water Resource Board and interested residents on 8 February 1983 to discuss the operating plan, specifically the discharge of flows higher than 500 cfs between 15 May and 1 June. After input from this meeting and further coordination with the Fish and Wildlife Service, it was recommended that 2,500 cfs be the maximum discharge until approximately 1 June. The actual release rate would likely be less than this amount, except during large or late floods. However, the flexibility to discharge up to this rate could greatly reduce the impacts in valley reaches affected by 500 cfs discharges.

61. The operating plan recommended after evaluation and coordination is shown on exhibit 3 and is described as follows:

- Draw pool down to pre-flood target elevation as required for predicted 30-day flood volume (exhibit 5).

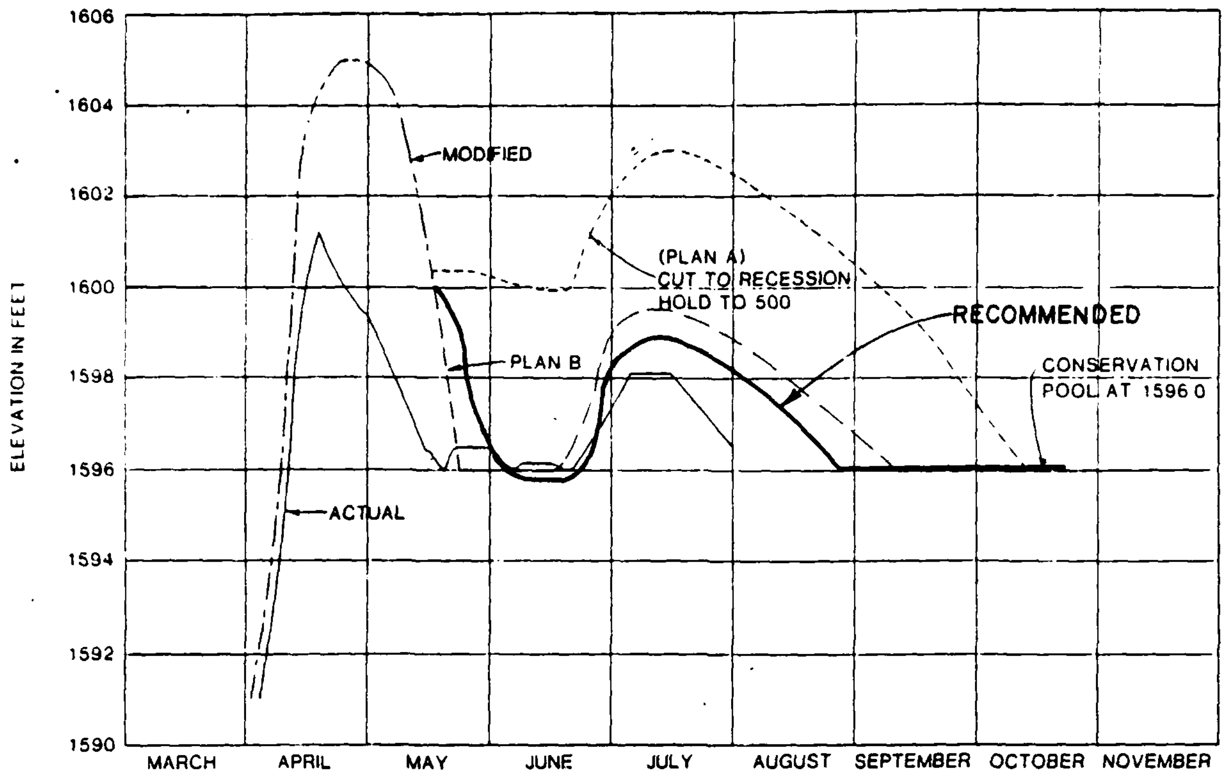
- Follow target flow curve for peak flows at Minot, based on predicted 30-day flood volume (exhibit 6).

- Release at target release rate, minimizing releases over 5,000 cfs, until elevation 1600 pool level is reached.

- On or about 15 May (or when pool falls below 1600, whichever is later), cut back releases to 2,500 cfs or a lesser discharge depending on timing, reservoir stage, and projected inflow of the flood.

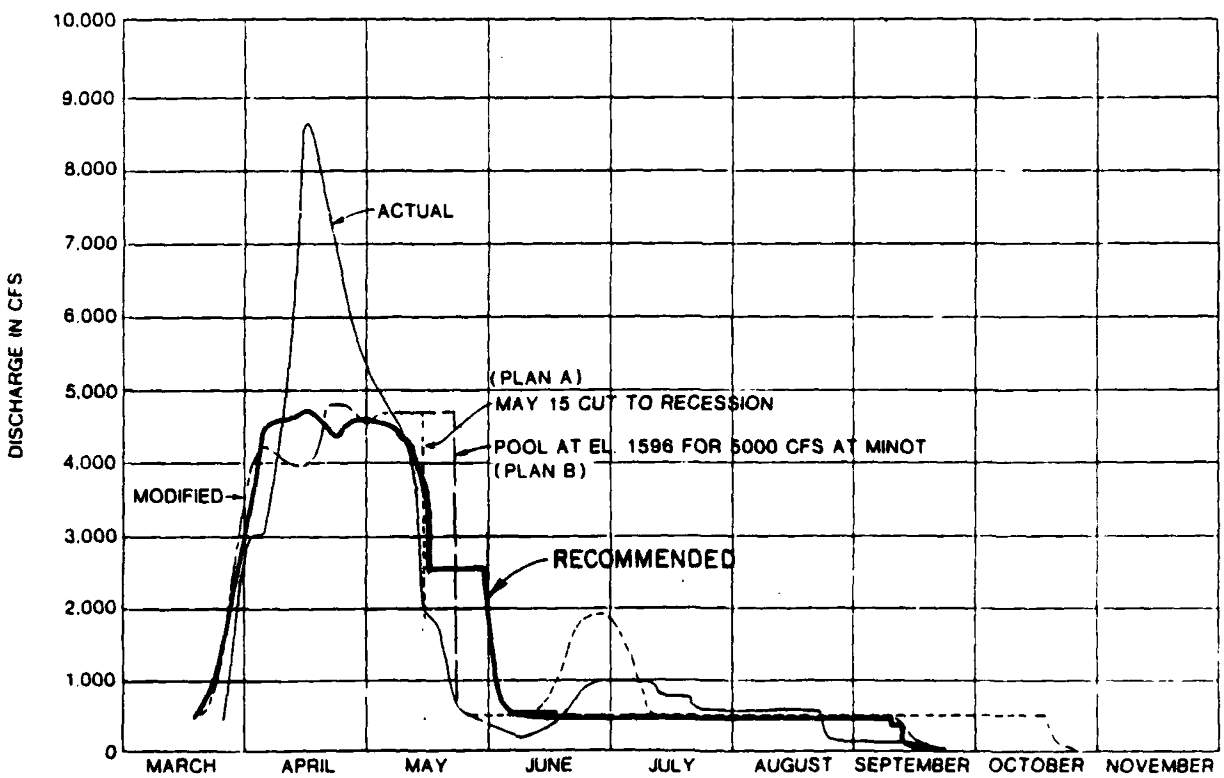
- On or about 1 June (as long as storage pool does not exceed elevation 1600), cut back releases to 500 cfs until the conservation pool level at 1596 is reached.

62. The changes from existing conditions resulting from the



RESERVOIR STAGE HYDROGRAPH

SOURIS RIVER-LAKE DARLING
1976 FLOOD



DISCHARGE HYDROGRAPH
(FOXHOLM GAGE)

EXHIBIT 3

recommended operating plan can be seen on the historic hydrographs on plates A28 - A33 in appendix A. The flood years chosen are representative of years of flooding over the past 35 years. Hydrographs for the other years have not been developed because they had low peak flows and any change in operation would produce little or no change in the "Reservoir Regulation" section of this report.

LAKE DARLING DAM

63. Formulation-level studies were done for the existing Lake Darling Dam to determine the most economic configuration for raising the dam 4 feet, as summarized in table 1. As discussed in the "Evaluation of Project Plan" section of this report, the definition of a 4-foot raise is considered to be a raise of the design pool by 4 feet. Since the existing ungated spillway provides reservoir storage to elevation 1601, including 3 feet of surcharge storage, a modified structure would have a design pool 4 feet higher, at elevation 1605. Storage to a higher elevation for a probable maximum flood (PMF) is considered acceptable with the condition that it does not exceed existing condition PMF stages.

64. Only two basic configurations were studied in detail. Both include a gated spillway and outlet works on the left abutment of the dam. The first alternative provides a spillway capable of passing the PMF without exceeding a reservoir stage of 1605. Under this alternative, the embankment would be raised only 4 feet to elevation 1610. The second alternative has a smaller spillway which is capable of passing the 500-year flood without exceeding elevation 1605; however, the PMF would reach a stage similar to existing conditions, or elevation 1609. The embankment crest with this design would be 1614.

65. Alternatives that were considered, but not given in-depth evaluation, were configurations providing for the following:

a. Ungated spillway.

b. Elevation 1620 design pool.

c. Elevation 1605 design pool and unrestrained maximum pool.

Ungated Spillway

66. The ungated spillway was not studied further because of excessive costs. The spillway crest length required to pass a PMF without exceeding existing condition elevations and providing for a 1605 design pool would be 1,540 feet. This is approximately 6 times as wide as the recommended spillway length and is

TABLE 1

ALTERNATIVE CONFIGURATIONS FOR LAKE DARLING DAM

	Existing	Ungated	Gated, 1605 Max. Pool	Gated, 1609 Max. Pool	Gated, 1620 Design Pool
Type of spillway	Ungated	Ungated	Gated	Gated	Gated
No. of spillway gates	---	---	7	5	4
Size of spillway gates (ft. high x ft. wide)	---	---	22 x 45	22 x 43	22 x 41
Outlet works design discharge (cfs @ 1596 headwater)	4,650	5,000	1,200	1,200	5,000
Elevations (ft.)					
Dam crest	1606	1614	1610	1614	1632
Spillway crest	1598 & 1602	1602	1584	1584	1600
Design Pool	1601	1605	1605	1605	1620
Maximum pool	1609	1609	1605	1609	1627
Stilling basin invert	---	---	1570.0	1571.5	1546
Top of spillway gates	---	---	1606	1606	1622
Invert of outlet works	1577	1577	1572.6	1573	1577
Spillway crest length (ft)	320 & 250	1,540	315	215	164
Frequency of 5,000 cfs release exceeded at dam	17-yr.	35-yr.	35-yr.	35-yr.	150-yr.
First costs (incl. bridge S & A, E & D)	---	---	23,740,000	20,500,000	24,800,000

about 40 percent of the entire valley width. Placement of a concrete spillway section in the base of the valley is not recommended because of poor foundation conditions and expected settlement. Therefore, a large portion of the spillway would have to be excavated from the left abutment, where there is a favorable foundation. It is obvious that the extensive excavation required would result in a more costly alternative than a gated spillway. An ungated spillway would have lower operation and maintenance costs; however, these savings would not offset the higher first costs. The gated spillway also has the advantage of providing for more flexible operation.

Elevation 1620 Design Pool

67. A structure that would be capable of storing water to elevation 1620 was evaluated in earlier studies and was reviewed in the current formulation analysis in terms of cost trends and comparisons of items within the structure. In the earlier studies, the elevation 1620 design pool was considered a constraint at the international border, any higher elevation being unacceptable to the Canadian government. The current project authorizes only an approximately 4-foot raise of the Lake Darling Dam. In addition to the authorizing constraints, a raise of this magnitude is considered unacceptable to local interests in Renville County. Therefore, other than updating the price levels, no further analysis was made of the 1620 design pool alternative.

Elevation 1605 Design Pool and Unrestrained Maximum Pool

68. As shown by the relative costs of the elevation 1605 and 1609 maximum pool designs, the cost of the structure is lower for the higher maximum pool ($23,740,000 at 1605 and $20,500,000 at 1609). The controlling factor in the lower cost for the 1609 design is the narrower spillway, which requires less excavation. Even with the 1609 design, more material will be excavated from the spillway construction than is required for construction of the embankment. The excess excavated material will be used to construct the approach roads and the berm downstream of the embankment. Therefore, there may be an alternative combining a higher embankment and narrower spillway that would be lower in cost than the 1609 design alternative.

69. An iterative formulation analysis would have been required to define the most cost effective combination of embankment height and spillway width. From the alternative configurations studied, it appears that a maximum pool level approximately between elevations 1610 and 1612 would result in the least costly alternative. However, there was no detailed analysis done to better define the most cost effective maximum pool design. Any design causing a maximum pool higher than the existing PMF level

or a design pool higher than elevation 1605 is considered to be beyond the intent of the project authorization, unacceptable to the local sponsor and, therefore, does not warrant further detailed studies.

Recommended Configuration

70. As previously discussed, the two primary alternatives studied in detail for this formulation analysis were the 1605 and 1609 maximum pool designs. Further discussion of hydraulic considerations for gate sizes, crest elevations, etc., is provided in appendix A.

71. Certain parameters in the formulation anaylsis were used as given constraints because previous studies for the Burlington Dam phase II general design memorandum (August 1978) had defined the most cost effective design. The left abutment is viewed to be the only reasonable location for the spillway because of foundation problems elsewhere in the valley. In view of the additional excavation required for a separate low-flow structure, a combined structure with low-flow outlets through the spillway piers is the most cost effective means of discharging the low flows. The spillway crest of 1584 was selected because it is considered to be the lowest acceptable elevation from a hydraulic standpoint. A higher crest would result in a wider spillway and therefore higher costs, as can be seen when comparing the 1605 and 1609 alternatives.

72. The comparison of the two primary alternatives shows a significant cost savings ($3,240,000 savings in first cost) for the elevation 1609 maximum pool design over the 1605 design. The costs were not annualized because the proportional difference would be the same annually as for the first costs. The operation and maintenance costs would be similar for both alternatives. Because the design pool of elevation 1605 is the same for both alternatives, other costs for upstream measures such as relocations, levees, and real estate would also be similar for both alternatives.

73. Because of the significant cost savings, the elevation 1609 design is the recommended configuration. It is recommended that a hydraulic model study be performed on the recommended design prior to preparation of a feature design memorandum.

REAL ESTATE ACQUISITION

General

74. The Upper Souris National Wildlife Refuge was authorized by Executive Order No. 7161 dated 27 August 1935. The EO authorized the purchase of approximately 40,000 acres of land to perpetuate

the waterfowl population in accordance with the Migratory Bird Conservation Act (45 Stat 1222). Lake Darling Dam was constructed to supply water to several downstream marshes and to the J. Clark Salyer Refuge in the lower Souris Valley. An attempt was apparently made to acquire fee title to at least elevation 1600, plus suitable upland habitat.

75. Most of the lands were purchased by the Bureau of Biological Survey, Department of Agriculture, during the 1930's. The legal instruments conveying title to the United States stated that purchase of the lands was authorized by various authorities. Three of those typically cited are: the Federal Emergency Relief Administration, 23 January 1935; the Migratory Bird Conservation Commission, 14 January 1934; and (49 Stat, 381-383), 15 June 1935.

76. The design pool of the 4-foot raise of the Lake Darling Dam is elevation 1605. Storage of the probable maximum flood to a stage not exceeding that for a similar event under existing conditions is viewed to be the maximum pool elevation. This stage is approximately elevation 1609. It is envisioned that the 1605 pool would not be exceeded for smaller than 500-year floods.

77. Storage to elevations higher than 1605 would have further impacts on already sensitive real estate and relocation needs in the reservoir. Also, storing water at damaging elevations for longer durations than would be possible with an ungated spillway crest at elevation 1602 is unacceptable to the local sponsor. Therefore, the formulation of the conceptual spillway design considered these social implications and local interest acceptance as well as economic optimization and maximizing downstream protection. Beyond the social aspect of the operating plan was the basic question of whether the authorization even allows a raise of the dam embankment by more than 4 feet for the maximum pool level. However, as previously discussed, the authorization is viewed to intend a similar increase in flood control storage as was recommended for the Burlington Dam project.

78. With the design pool at elevation 1605, it will be necessary to acquire an interest in approximately 1,250 acres of privately-owned lands behind Lake Darling Dam to accommodate the proposed increased flood pool. These 1,250 acres include a portion of McKinney Cemetery and Renville County Park, a 70-acre setting occupied by more than 90 seasonal cottages on privately-owned lots. The acreages are to elevation 1607, which includes 2 feet of freeboard.

79. Also included within these 1,250 acres are approximately 80 acres of land located along various coulees and creeks which drain into the valley at several points adjacent to the east and west boundaries of the refuge. These areas will be referred to

in this report as break out points.

80. The Lake Darling project is a compromise plan agreed to by the local interests, and they are strongly opposed to fee acquisition in connection with the raise of the dam. Therefore, alternatives to fee acquisition are being considered during the development of an acquisition program for this project. The following discussions concern the alternatives considered at various sites within the project area.

Land North of Upper Souris Refuge

81. About 1,100 acres of privately-owned land affected by the elevation 1605 design pool are located upstream of the existing north boundary of the Upper Souris National Wildlife Refuge. There are no structures within these 1,100 acres. The bulk of this land is used for agricultural purposes and is located on either side of the Souris River. These lands are subject to frequent natural spring flooding but usually dry out sufficiently to permit the planting and harvesting of a crop each year.

82. The permanent pool or conservation pool at Lake Darling Dam will remain at elevation 1596. The flooding which will occur on those lands above elevation 1596 and below elevation 1605 will be more frequent and of a longer duration than that which would occur under existing conditions. However, it is felt that the frequency and timing of the flooding will permit the continued use of these 1,100 acres in a manner similar to their present use.

83. Although there are no structures located below elevation 1607, portions of some farm access roads within the 1,100 acres do lie below elevation 1607. With little cost, these roads could easily be raised to an elevation above 1607, which would ensure their continued use by the landowner during periods of inundation.

84. The Fish and Wildlife Service feels that these lands would not be suitable for habitat use and, therefore, does not object to the acquisition of standard flowage easements over the 1,100 acres.

85. A standard flowage easement would permit the landowner to continue to use his lands as they are presently being used and would keep the lands on the local tax rolls. It is recommended that a standard flowage easement be acquired over the 1,100 acres. Costs for raising any low-lying private access roads that would be affected by higher reservoir stages would be taken into consideration in the flowage easement payment. Table 2 summarizes the real estate alternatives for the land north of the Upper Souris Refuge.

Table 2

Real Estate Alternatives - Land North of Upper Souris Refuge

Proposed Plan for Additional Reservoir Lands	Cost to Implement	Policy for Plan by Citation	Waivers Required	Remarks
Standard Flowage Easement	$250,000	EP 405-1-2	OCE approval of DM	1100 acres $\pm$ of privately-owned lands between elevations 1596 and 1607 upstream from Lake Darling Dam will be subjected to more frequent flooding as a result of the 4-foot raise. Standard flowage easement acquisition is recommended for 1100 acres which will still be suitable for agriculture. Access road raises may be required.
Fee Title	$680,000	EP 405-1-2	OCE approval of DM	

Breakout Points

86. The Upper Souris National Wildlife Refuge above Minot, North Dakota, consists of approximately 32,000 acres owned in fee and operated by the Fish and Wildlife Service. The refuge above Lake Darling Dam is about 1 1/2 miles wide and extends northerly upstream about 30 miles from the dam.

87. At the present time, there are approximately a half dozen locations where the lake behind Lake Darling Dam "breaks out" or extends beyond the refuge boundary onto privately-owned lands. Once the 4-foot raise of the dam is completed and the project is put into operation, the new design pool elevation (1605) will "break out" of the refuge boundary at approximately 20 locations. These break out points are, for the most part, confined to coulees and creeks draining into the valley. They range in size from 1 to 5 acres, and their combined total is about 50 acres. All of the real estate required for these various break out points is unimproved, except for one area.

88. At this one location, a large number of structures on the Ben Eckert Ranch are clustered together, including the residence. These structures serve as the headquarters for the entire 700-acre ranch. A low levee and diversion appear to be more cost effective than acquisition of the ranch. Without some form of protection, these buildings will be adversely affected by the operation of the reservoir, and their removal would be required. If it becomes necessary to acquire the structures and raze them, it is highly likely that it would be necessary to acquire the entire ranch as an uneconomic remnant. It is estimated that this would cost $800,000; however, even the cost of the needed area of the ranch, structures, and severance damages of $450,000 would exceed the cost of protecting the area with a levee.

89. On a preliminary basis, it appears to be feasible to protect the buildings on the Eckert Ranch with an SPF levee to prevent impoundment from the reservoir. Interior drainage could be diverted to avoid inundating the buildings. It is estimated that this structural solution would cost approximately $227,000.

90. The Fish & Wildlife Service would prefer that fee title be acquired to these break out points so that it can more efficiently manage its refuge. The Service has indicated, however, that it may accept an easement over these break out points, if, in addition to the right to overflow, flood, and submerge, the easements permit fencing to be constructed and service roads to be operated and maintained. Although fencing around an easement area would not be permitted, service roads on the easement areas are viewed to be acceptable. The roads would constructed at an elevation which would minimize damages from waters stored in Lake Darling. Fences that would cross a newly aligned service road

would be modified with gates, cattle barriers, etc., as necessary to accommodate the use of the service roads.

91. Table 3 summarizes the real estate alternatives for the breakout points. In keeping with the wishes of local interests, acquisition of flowage easements with rights to construct roads is recommended. It is also recommended that a levee and diversion be constructed at the Ben Eckert Ranch to eliminate the possible need to acquire the entire ranch.

Table 3

REAL ESTATE ALTERNATIVES -
BREAK OUT POINTS

Proposed Plan for Break Out Points	Cost to Implement	Policy for Plan by Citation	Waivers Required	Remarks
Fee Title	$30,000	EP 405-1-2	OCE approval of DM.	Currently there are approximately a half dozen break out points. The new design pool elevation (1605) will cause approximately 20 break out points comprising approximately 80 acres. Land at break out points is unimproved except for the Eckert Ranch buildings. FWS would prefer fee title be acquired at break out points so the Refuge can be more efficiently managed. Local interests are opposed to fee acquisition.
Flowage Easement	$25,000	EP 405-1-2	OCE approval of DM.	FWS has indicated that it may accept an easement over these break out points. However, if only a flowage easement is acquired, in addition to the rights obtained in a standard flowage easement, FWS would like the right to fence the property and maintain service roads.
Eckert Ranch				
Levee:	$227,000	EP 405-1-2	OCE approval of DM.	
Acquire structures and needed area of ranch	$450,000	EP 405-1-2	OCE approval of DM.	
Acquire entire ranch as uneconomic remnant	$800,000	EP 405-1-2	OCE approval of DM	

McKinney Cemetery

92. McKinney Cemetery, located one-fourth mile south of State Highway 5 on the west edge of the river valley, contains about 250 graves within a 4.3-acre site. A portion of the cemetery, including approximately 50 graves, will be inundated by flood storage up to the reservoir design pool elevation 1605. McKinney Cemetery is on the National Register of Historic Places.

93. Fee acquisition of the required right-of-way would require the relocation of all or a portion of the graves within the cemetery. Local interests oppose this plan because of fee acquisition and because of the need to relocate the graves.

94. Acquisition of the standard flowage easement would satisfy local interests opposed to fee acquisition. However, relocation of the graves would still be required.

95. Flood proofing those graves affected by the raised level of Lake Darling would permit the cemetery to remain in place. This plan would involve placing fill an average of 5-6 feet deep over the lower portion of the cemetery area to the design pool elevation. Grave markers, if any, would be relocated directly above their present locations. Local interests and the State Historic Preservation Officer are opposed to this plan because they do not wish to have the cemetery disturbed at all. Also, there is some possibility that the graves may still have to be relocated directly upward.

96. Another alternative would be to build a levee on Fish and Wildlife Service lands adjoining the cemetery. The Fish and Wildlife Service has given a preliminary indication that it would not object to this plan. With this option, it would not be necessary to acquire a real estate interest in cemetery lands, relocate any of the graves, or construct a levee on cemetery lands. All of the protective measures could be constructed on Federally-owned lands. For these reasons, the levee is the recommended alternative. A provision to eliminate ponding in the cemetery is required. Table 4 summarizes the real estate alternatives for McKinney Cemetery.

Renville County Park

97. Renville County Park, also known as Mouse River Park, serves as a central recreation area for Renville County. Although rustic, the wooded area is also a haven from the sun and wind which is so prevalent on the North Dakota plains. There are approximately 90 privately-owned seasonal cottages and five county-owned buildings, including a cafeteria, bar, roller-skating center, and auditorium in the 70-acre park. An estimated seven permanent, year-round residents live at the park.

Table 4

Real Estate Alternatives -
McKINNEY CEMETERY

Proposed Plan for McKinney Cemetery	Cost to Implement	Policy for Plan by Citation	Waivers Required	Remarks
Fee Acquisition	$300,000 Ordinarily, just compensation for the acquisition of an existing cemetery site will consist of furnishing a new site comparable to the old site, plus disinterment and reinterment of the bodies, and transferring monuments and other facilities to the new site.	EP 405-1-2 ER 1180-1-1, Para. 73-208 and 78-800 et seq.	Cemetery Relocation Plan approved by OCE.	A portion of the cemetery is below elevation 1605 and will be subject to flooding as a result of the dam raise. Fee acquisition will require relocation of the graves within the cemetery. Local interests oppose fee acquisition and relocation of graves. Cemeteries subject to flooding may be allowed to remain only with the specific approval of the Chief of Engineers.
Standard Flowage Easement		EP 405-1-2 ER 1180-1-1, Para. 73-208 and 73-800 ff	Cemetery Relocation Plan approved by OCE.	Acquisition of a standard flowage easement would satisfy local opposition to fee acquisition but graves would be subject to flooding and relocation would be required. Cemeteries subject to flooding may be allowed to remain only with the specific approval of the Chief of Engineers.
Flood proofing	$200,000±		OCE must approve DM.	Graves may still have to be raised and local interests do not wish to have the cemetery disturbed.
Levee on FWS Lands	$127,000±	EP 405-1-2	OCE approval of DM required. FWS must agree to permit construction on Refuge lands.	Land would not have to be acquired and graves would not be disturbed. Provision for elimination of ponding in the cemeteries is required. If the Levee is not compatible with the purposes for which the Refuge was established, mitigation may be required.

98. County residents recognize the importance of the park in their local history as the setting for political rallies, religious and civic meetings, educational programs, and recreational activities. The park was established in 1913 by the Mouse River Loop Chautauqua Association and it thrived for a quarter of a century. Such celebrities as William Jennings Bryan of the Populist Party, Lawrence Welk, Billy Sunday, and numerous others performed at the park. In addition to the Chautauqua tent and later an auditorium, other buildings in the seasonal community included a dance pavilion, picture show house, small zoo, and numerous summer cottages and tent floors. Most of these original buildings have been removed and it appears that the primary remaining value of the park in a historical sense is the knowledge of the events and activities that occurred and the natural park setting that still exists.

99. The average elevation of the park is 1600 feet above msl, and the first floor elevation of most of the structures is between 1601 and 1603. The proposed design flood pool elevation is at 1605, so all of the structures within Renville County Park would be subject to some periods of inundation.

100. Acquiring fee title to all lands within the park is strongly opposed by opponents of the Burlington Dam Project. The Fish and Wildlife Service would prefer the park lands to be acquired in fee and become part of the Refuge.

101. Acquiring fee title with reservation of a life estate for current landowners in the park does not satisfy local opposition to fee title acquisition. Furthermore, it would limit the proper operation of the project because complete control of the project area would be lacking.

102. Acquiring a standard flowage easement does not permit structures intended for human habitation to be constructed or maintained on the land. Therefore, this alternative would not satisfy the local concern about continued use of the park. All recreational cabins and permanent dwellings would be eliminated.

103. Revising the standard flowage easement to allow landowners to place mobile homes and recreational vehicles on their lots in the park for a specified period of time would permit continued use of the park after the dangers to life or property from flooding have passed. Requiring the mobile homes and recreational vehicles to be moved each fall would prevent temporary dwellings from becoming permanent and would eliminate the possibility of damage to them during floods.

104. The county-owned buildings would have to be flood proofed or relocated to higher elevations within the park to avoid inun-

dation. Existing pit toilets and sanitary sewage treatment (if any) would not be permitted if this option is selected. Sewage would have to be placed in holding tanks and occasionally hauled away by commercial haulers at the landowner's expense.

105. The seven permanent, year-round residents living at the park would be required to relocate to a permanent location outside the park if this option is selected, although they would be permitted the same periodic use of the park as the part-time residents.

106. Allowing owners to decide whether they wish to sell fee or revised flowage easement would create a checkerboard pattern of Government ownership and would create management problems.

107. Flood proofing all of the structures in the park would be difficult because of the poor condition of many of the buildings, but it would permit eligible residents to remain in place. This alternative would have to be economically justified, however, and it is likely that flood proofing would not be possible or would not be economically feasible for many residences. Continued use of toilets by residents would not be permitted nor could access be maintained during periods of high water. This option could create management problems by having privately-owned buildings within the proposed design flood pool. In addition, flowage easements would still have to be acquired over the lands to be inundated by the proposed flood pool regardless of whether the structure on the land was flood proofed.

108. Providing a cutoff channel to reroute flood waters away from the park, together with a levee to protect the park, is an option. The levee and channel could be constructed on Fish and Wildlife land adjacent to the park, so it would not be necessary to acquire any private properties for levee or channel construction. The existing channel would continue to carry Souris River flows except during periods of high water, when the flows would be rerouted through the new channel. Residents would have access maintained from the east even during periods of high water. Interior drainage could be handled by a pump station on FWS lands. This option would permit the continued year-round use of the park by all residents and would not require the acquisition of any real estate interest from private landowners. Levee and channel maintenance would be the responsibility of the Corps.

109. The estimated cost of a levee that provides 100-year degree of protection is $1,200,000. The top of the levee for this level of protection would be approximately at elevation 1610. To provide standard project flood protection to the park area a levee 5 feet higher would be required (elevation 1615). The estimated cost of the SPF levee is $2,000,000. Because the area is not an urban or highly concentrated development where overtop-

ping would result in major hazards to life or unusually severe property damage, as discussed in EP 405-1-2, a standard project flood levee is not viewed to be necessary. As indicated in the "Local Cooperation" section of this report, the local sponsor agrees to hold and save the United States free from damages in the event the reservoir levees are overtopped. Cost estimates indicate that the 100-year levee and channel alternative is economically justified, most cost effective, and socially acceptable. Because this alternative has the added advantage of permitting the continued use of Renville County Park by all residents and appears acceptable to the Fish and Wildlife Service, it is the recommended course of action. Table 5 summarizes the real estate alternatives for Renville County Park.

ROAD RELOCATIONS

110. There are 10 public roads crossing the Souris River between Lake Darling Dam and the international border at Saskatchewan, a span of 83 river miles or 40 valley miles. These roads are identified on table 6 and are shown on plates 1 and 6. The three bridges farthest upstream, Barber Bridge, Bluell Bridge, and FAS 3804, are at or above the design pool level of 1605 and therefore do not require modification as a result of the Lake Darling Dam raise. The approximate frequency and duration of impacts on these crossings by high water stages is shown on table 7. The roads vary widely in quality and traffic loads. Only State Highways 5 and 28 have a bituminous surface. Most of the roads follow section lines. The state highways are maintained by the North Dakota State Highway Department, and the county or township is responsible for maintenance of other roads. Federal aid secondary routes are eligible for limited Federal funds for maintenance and improvements.

111. The Souris River is generally a slow rising river with low velocities. However, because of its wide valley and long flood durations, the road crossings could be subjected to wave damage from reservoir storage. Further discussion of the hydraulic considerations for the road crossings is provided in appendix A of this report. Because there is a limited number of roads in the project area and most of these do not have adequate surfacing, the detour distances and times could be significant if a road is closed. During evaluation and coordination with the North Dakota Highway Department and Renville County officials concerning the appropriate measures required for the roadway network in the reservoir area, the following factors were considered:

a. Traffic volume.

b. Type of traffic (grain or oil transport trucks, local, farm equipment, through traffic, etc.). (See table 8.)

Table 5

REAL ESTATE ALTERNATIVES -
RENVILLE COUNTY PARK

Proposed Plan for Renville County Park	Cost to Implement	Policy for Plan by Citation	Waivers Required	Remarks
Fee Title Purchase	$1,600,000	EP 405-1-2 Chap. 2, Joint Land Acquisition Policy for Reservoir Projects COE & FWS.	OCE approval of DM if elect to acquire fee.	Acquisition of fee title is strongly opposed by local residents. Lands below the maximum flowage line of the reservoir are normally acquired in fee. Structures which would interfere with the operation of the project or which would be substantially damaged by inundation are prohibited below the guide taking line unless approved by the Chief of Engineers.
Flowage Easements (mobile homes allowed part time)	$1,300,000	EP 405-1-2 Chap. 2 Joint Land Acquisition Policy for Reservoir Projects.	OCE approval of REDM and DM providing for human habitation in reservoir area.	COE policy prohibits habitation in reservoir areas below the top of the flood pool plus a reasonable free board. Human habitation places undue limitations on the proper operations of the project in regard to safety of people in the area and the orderly public use of the lake.
Flowage Easements (Flood proofing)	Flowage Easement: $300,000 Flood proofing: $1,770,000 Assumes all structures flood proofed.	EP 405-1-2 Para. 2-12(b) Joint Land Acquisition Policy for Reservoir Projects. EP 1165-2-314 Flood proofing.	OCE approval of REDM and DM providing for human habitation in reservoir area.	Many structures in Park cannot be feasibily flood proofed due to their poor condition. The alternative to flood proofing would be acquisition and removal of the structures. This alternative was recommended by local interests who oppose fee acquisition.
Levee and Diversion (No Acquisition)	Land owned by USA, administered by FWS. Cost of Levee and channel: $1,200,000 (100-year protection) $2,000,000 (SPF protection)	EP 405-1-2 Chap. 2	No waiver required- must have permission to build on FWS lands and OCE approval of DM. Flowage easements or assurances from local interests necessary for levees that could be overtopped.	This alternative satisfies the local opposition to fee acquisition. If the Levee and diversion are not compatible with the purposes for which the Refuge was established, mitigation may be required. SPF levees are not viewed as necessary within guidelines of EP 405-1-2.

Table 6

LAKE DARLING DAM RESERVOIR CROSSINGS

Crossings	Existing Elevation			Average Daily Traffic	Approx. River miles above Lake Darling Dam	Recommended Raise (Min. Elevation)
	Bridge Deck	Low Chord	Min. Approach			
Lake Darling Dam	N/A	N/A	1598	300	---	1614
Grano Crossing (FAS 3828)	1604.4	1601.6	1602.4	250	18	1607
State Hwy. 28	1605.5	1602.5	1605.5	120	26	1607
Dam 41	N/A	N/A	1596.5	15±	42	Upgrade-1596.5
State Hwy. 5	1609	1605.0	1604.8	440	45	1607.5
Renville Co. Park Bridge	1605.5	1602.2	1600	116	48	1598 (Texas Crossing across diversion channel)
Renville Co. Rd. 9 (FAS 3809 or Swenson Bridge)	1608	1606	1605	70	55	Stabilize
Barber Bridge (old FAS 759)	1612	1610	1612	65	65	No change
Bluell Bridge	1621	1619	1615	92	73	No change
FAS 3804	1620	1618	1620	72	79	No change
Soo Line Railroad	1605.8(1)	1603.3	1605.8(1)	160 cars/week	24	1608(1)

(1) Top of rail

Table 7

RESERVOIR CROSSINGS-FREQUENCIES AND DURATIONS OF INUNDATION

Crossings	Exist. Min. Elev.	Recom. Min. Elev.	Frequency of Inundat. (Years)[3] At Min. Elev.			100-Year Flood Duration (Days) 2' Below Min. Elev.			100-Year Flood Duration (Days) At or Above Min. Elev.		
			Preproject	Post Proj. w/o Modif.	Post Proj. w/ Modif.	Preproject	Post Proj. w/o Modif.	Post Proj. w/ Modif.	Preproject	Post Proj. w/o Modif.	Post Proj. w/ Modif.
Lake Darling Dam	1598	1614	20	N/A	PMF	---	---	---	26	N/A	0
Grano Crossing (FAS 3828)	1602.4	1607	70	15	500+	14	40	17	3	35	0
State Hwy. 28	1605.5	1607	190	200	500+	0	30	17	0	0	0
Dam 41	1596.5	1596.5	1	1	N/A	All Year	All Year	All Year	40	75	N/A
State Hwy. 5	1604.8	1607.5	75	20	170	10	34	17	2	18	0
Renville Co. Park Bridge	1600	1598[2]	10	10	1	30	70	All Year	35	40	70
Renville Co. Rd. 9 (FAS 3809 or Swenson Bridge)	1605	1605	20	20	N/A	40	40	N/A	5	20	N/A
Barber Bridge (Old FAS 759)	1612	1612	10	10	N/A	40	40	N/A	35	35	N/A
Bluell Bridge	1615	1615	10	10	N/A	40	40	N/A	35	35	N/A
FAS 3804	1620	1620	10	10	N/A	40	40	N/A	35	35	N/A
Soo Line Railroad	1605.8[1]	1608[1]	300	500	500+	7	37	28	0	28	0

(1) Top of rail
(2) Elevation of proposed Texas crossing
(3) Does not consider wave action

Table 8

PRESENT TRAFFIC USE ON KEY ROAD CROSSINGS
IN RESERVOIR AREA

Road Crossing	Ave. Daily Traffic	% Local Auto Traffic	% Thru Traffic	% Trans. of Farm Prod.	% Movement of Farm Mach.	% Oil Trans	% Public Use (School Bus & Mail Emergency Vehicles, etc.)
Lake Darling Dam	300	25	5	20	15	30	5
Grano Crossing	250	10	10	25	15	25	15
State Hwy. 28	120	25	15	35	10	10	5
State Hwy. 5	440	15	40	20	5	15	5
Renville Co. Rd. 9 (FAS 3809)	70	15	20	30	20	5	10

c. School bus and mail routes.

d. Frequency and duration of road out of service.

e. Alternative routes available.

f. Whether road is essential to national defense.

g. Effect of a road raise on upstream real estate needs.

112. Development of a roadway network that would comparably serve transportation needs after the project is completed must consider the impact of road raises on upstream private lands. As discussed in appendix A, floods of various frequency up to the probable maximum flood of 99,800 cfs were routed through the reservoir. A combination of roadway approach elevations and bridge openings were used to determine adverse impacts of water stages between preproject and postproject conditions in the upstream reaches of the reservoir. Adverse impacts would require that an interest be acquired on the affected land and improvements. Because of strong local opposition to real estate acquisition for reservoir storage, adequate bridge openings to minimize backwater affects were considered essential for implementation of the project.

113. In determining the appropriate approach elevations of the road crossings, consideration was given to keeping the roads passable except for infrequent floods, balanced with providing minimum head loss during larger floods. The roadways would be overtopped and significantly reduce the size of required bridge openings during large floods. The minimum road elevations were controlled by wave action for the design pool level of 1605. Two feet of freeboard above the flat 1605 pool for wave action were found to be adequate for State Highway 28 and Grano Crossing. At State Highway 5, the 100-year profile, plus freeboard for wave action, is the controlling criteria, which requires 2.5 feet over the flat 1605 pool. With the minimum bridge bearing elevations above the 100-year water levels, as required by the North Dakota Highway Department, it was determined that the existing bridge spans would be adequate to pass various frequency flows without substantial increase in real estate needs upstream of the Upper Souris Refuge. Only the bridge span at State Highway 5 would have to be enlarged to satisfy the constraint of upstream real estate acquisition. Without the increased bridge span there would be an adverse effect of 0.5 foot higher stage for the 200-year flood at the upstream boundary of the Upper Souris Refuge. As stated earlier, the strong local opposition to real estate acquisition in the reservoir area is viewed as a controlling factor in the bridge configuration. The larger bridge opening at State Highway 5 would also serve to reduce velocities under the

bridge, reducing the stage of flooding on upper refuge lands, Renville County Park, and the McKinney Cemetery.

114. On the basis of the above factors and economic considerations, recommended priorities for road relocations are as follows:

a. Provide bridge across raised Lake Darling Dam spillway.

b. Raise State Highway 5 to elevation 1607.5 and increase bridge opening.

c. Raise Grano Crossing to elevation 1607.0.

d. Raise State Highway 28 to elevation 1607.0.

e. Provide roadway on diversion channel weir at Renville County Park.

f. Stabilize Renville County Road 9.

g. Upgrade dam 41 road on spillway at same elevation.

Bridge Across Lake Darling Dam Spillway

115. The road which crosses the Souris Valley at the site of the Lake Darling Dam is a Federal aid secondary route with two designations (FAS 3828 and 5126) because it is on the Renville-Ward county line. The road passes through the spillway downstream of the ogee crest, which has an elevation of 1598. The gated spillway of the raised dam would have a lower ogee crest elevation of 1584 and a deeper stilling basin. Therefore, a bridge is the only practical means of providing a public road over the dam.

116. The road has an average daily traffic volume of 300 vehicles. Minot Air Force Base personnel use this road extensively for traveling to the numerous missile facilities in the area. The Carpio school district is divided by the river. Therefore, school bus service for the students east of the valley is a serious problem when the road is closed. There is a mail route on the road. The road is also used by local people for transportation of grain, farm machinery, and oil. The bridge across the spillway is considered essential for traffic in the area. Without access across the Lake Darling Dam, traffic would have to rely on Grano Crossing, 11 miles upstream, or Bake Bridge, 7 miles downstream. During a large flood, the Lake Darling Dam crossing would be necessary because some of the reservoir crossings could be inundated.

State Highway 5

117. Highway 5 is the most heavily traveled route in the reservoir area, having daily average traffic flows of 440 vehicles. Highway 5 is one of the few east-west highways spanning the entire State of North Dakota. It is used extensively for commercial traffic as well as for school bus routes, mail routes, fire protection, ambulance service, and local resident traffic.

118. The preproject frequency of inundation is about once in 75 years, while under postproject conditions, the frequency would be about once in 20 years. Such an interruption of traffic on this important highway would result in hardship and added expenses to all concerned. It is recommended that this crossing be raised to elevation 1607.5.

Grano Crossing

119. The average daily traffic load is 250 vehicles. Transportation of oil from an oil field west of Lake Darling to oil depots in the Maxbass and Glenburn areas is a major contributor to the heavy traffic load. Grain being hauled to elevators in Grano and Lansford also contributes to the commercial traffic load. The crossing is used extensively by local residents for movement of farm machinery, use of the Grano recreation area on the west shore of Lake Darling, and other local travel.

120. Assuming State Highway 28 is raised to elevation 1607, the detour distance during reservoir storage without a raise of Grano Crossing is 7 miles. A large flood which inundated Highway 28 would involve at least 16 miles of additional travel to cross the valley via Lake Darling Dam. The oil and grain industry is very important to the economic well-being of Renville County. It is recommended that this crossing be raised to elevation 1607.0.

State Highway 28

121. This roadway, which crosses Lake Darling near Greene, North Dakota, was originally classified as a Federal aid secondary road (FAS 752). In 1968 this route was transferred to the State highway system. It is the major north-south route in the reservoir area, although the average daily traffic load is only 120 vehicles. This lake crossing is important for local traffic, including movement of farm equipment and grain shipment, and as a mail route.

122. The existing bridge was built in 1934 and was raised 10 feet in 1936. The 7-span timber structure has a clear roadway width of 22 feet and has been posted with a 10-ton weight limit. The estimated remaining life of this bridge is less than 10

years. During preparation of the feature design memorandum on road relocations, discussions will be held with the North Dakota State Highway Department to determine whether any of the improvements would be considered to be betterments and to establish more detailed design features necessitated by the project.

123. The shortest detour along existing roads, in lieu of a raise, would be northward 7 miles to State Highway 5. The nearest crossing to the south is Grano Crossing, 7 roadway miles downstream of Highway 28, or Lake Darling Dam, which is 20 roadway miles downstream.

Roadway on Weir at Renville County Park

124. The crossing at Renville County Park provides access to the park from both sides of the valley and is used as a local route. The recommended levee would improve protection for the park access from the east because the bridge and the park itself would be protected from the 100-year flood. However, the diversion channel west of the park would bisect the access road from the west. Placing a bridge over the diversion channel is not considered practical because of the cost, low traffic volume, and the effect of causing higher water stages upstream. To permit the crossing to be used with a minimum loss of serviceability, a roadway across the diversion weir is proposed. The weir would be at elevation 1598 and, therefore, subject to longer and more frequent inundation that the existing road. The cost of the roadway on the weir is included in the levee cost at Renville County Park.

Stabilize Renville County Road 9

125. The minimum approach elevation at Renville County Road 9 (Swenson Bridge) is elevation 1605. Because the top of the roadway would be subject to water levels at higher stages for longer durations, it is recommended that the roadway embankment be further stabilized with riprap and stabilized aggregate. Raising the approach would cause higher flooding stages upstream and is not recommended.

Upgrade Dam 41 Roadway

126. As an operational feature of the Fish and Wildlife Refuge modifications, dam 41 is being upgraded so it can continue functioning as a refuge management structure. Therefore, the costs of upgrading the spillway and access road are included in the costs of fish and wildlife measures. Because the roadway at this site is a township road, improving its serviceability would benefit local traffic as well as the refuge. However, because of the longer reservoir storage in flood years, the road will be inundated for longer periods of time.

SOO LINE RAILROAD

127. The Soo Line Railroad crosses Lake Darling near Greene, North Dakota. The minimum elevation of the present crossing is about 1604 at the base of the ballast and 1605.8 at the top of the rail. The crossing consists of an earth-fill embankment with stone protection, a 300-foot wood trestle bridge, and a single-line, east-west track. The bridge was built in 1905. In 1920, fill was placed around the cedar piles for approximately 200 feet on either side of the main channel to reduce the bridge opening width from 700 feet to 300 feet.

128. The track is operated tri-weekly, bi-weekly, or daily, depending upon seasonal business. Most of the cargo is grain, but fertilizer, fuel, and farm machinery are also carried. The average weekly traffic across Lake Darling is 160 cars. This track has been used as a detour route for mainline traffic during periods of high water in Minot. Branch lines, such as this Lake Darling crossing, are becoming more critical to the railroad company and the local farm economy, especially in North Dakota, where unit trains are being more widely used for grain transport.

129. The Soo Line crossing was considered with the road crossings, as discussed previously in this report, during evaluation of the frequency and duration of inundation for preproject and postproject effects. In cooperation with Soo Line Railroad Company officials, evaluation was made of the modifications necessary for the railroad company to operate after project construction in a manner at least as well as under existing conditions. Consideration was given to the possibility of rerouting traffic during periods of high water with compensation paid for the estimated additional costs. This alternative is viewed by the railroad to be totally unacceptable. The long durations of flooding in the Souris Valley could seriously impair the serviceability of the line and adversely affect future business. During periods of high reservoir storage, the main line through Minot would likely also be out of operation also because of high water. With both railroad lines out of operation, rail transportation to and from the western part of North Dakota and Montana would be greatly hindered.

130. The recommended modification for the Soo Line Railroad crossing is to raise the top of the track to elevation 1608. The track would be raised 1 foot higher than the roadways because the ballast is more subject to washing and additional freeboard is required.

DESCRIPTION OF PROPOSED STRUCTURES AND IMPROVEMENTS

LAKE DARLING DAM

131. The existing dam is an earth-fill structure about 33 feet high, and the crest is at elevation 1606. The dam includes a 320-foot-long uncontrolled service spillway on the left abutment, a 250-foot-long emergency spillway on the right abutment, and a 2-barrel gated low-level outlet works.

132. The two uncontrolled spillways and the existing low-flow outlet will be replaced with a new control structure located on the left abutment. The new structure will be a gated spillway with low-flow outlets through the gate piers. A 30-foot-wide bridge will be provided across the spillway to maintain the public highway that presently crosses the dam.

133. The design flood pool at Lake Darling Dam will be raised 4 feet to elevation 1605. This elevation will not be exceeded for all floods up to and including the 500-year flood. During larger floods, the pool will not exceed the elevation that would occur with the present Lake Darling Dam. The probable maximum flood would attain an elevation of 1609 in the present structure, assuming the dam does not fail. Elevation 1609 is used as the maximum pool level for the spillway design flood. The crest of the raised dam will be at elevation 1614; the dam will have a maximum height of about 41 feet above the streambed, a top width of 40 feet, and a crest length of about 3,700 feet. The spillway will be located on the left abutment and will consist of an approach channel, a gated ogee control section, and a stilling basin. The low-level outlet works, located in the spillway pier, will consist of four gated rectangular conduits and will use the spillway stilling basin and discharge channel. A plan of the raised dam is shown on plate 2.

Embankment

134. The modified embankment will have a rockfill section on the upstream face and an impervious fill zone. The embankment will have 1V on 3.75H side slopes upstream and downstream. A downstream berm will be constructed with excess excavation material from the spillway construction. It will have a 1V on 50H slope and terminate with a 1V on 3H slope. A sand drain will be placed on the downstream slope of the existing embankment and will extend to the toe of the new impervious fill zone. Finger drains 10 feet wide and 50 feet on center will extend from the toe of the new impervious fill zone to the toe of the berm. A perforated pipe toe drain will be installed at the toe of the berm to collect and monitor seepage. Slope protection will consist of 18-inch riprap on 9-inch bedding on the upstream slope above elevation 1600.0, and 15-inch riprap on 9-inch bedding on

the downstram face of the berm. The downstream face of the dam and the top of the berm will be topsoiled and seeded. Embankment details are shown on plate 3.

Spillway

135. The spillway will be located in the left abutment and founded on the Tongue River Formation. The spillway will consist of an approach channel, a gated ogee control section, a stilling basin, and a discharge channel to convey the water to the natural river channel. Spillway details are shown on plate 4. The ogee section will consist of five bays, each controlled by a 43-foot-wide by 22-foot-high tainter gate. Each bay will be designed to pass 19,960 cfs with a 4-foot surcharge on the reservoir. Each gate will be lifted by an individual gate hoist. The stilling basin will be 255 feet wide and 80 feet long.

136. The spillway is designed to pass the probable maximum flood at pool elevation 1609. The coefficient of discharge, after adjustment for submergence, is 3.80. The inflow and outflow hydrographs for the probable maximum flood routing, the spillway discharge rating curve for all five gates fully opened, the area-capacity curve for Lake Darling, and the tailwater rating curve are shown on plate 5. The approach channel nominally will be at elevation 1571.5 and will slope to the reservoir for drainage. The crest of the ogee section will be at elevation 1584.0.

137. The horizontal stilling basin was designed for a discharge of 99,800 cfs with a tailwater elevation of 1598.3. The required basin length is 80 feet and the width is 255 feet. The ogee crest and stilling basin will be founded on the Tongue River Formation. The permanent cut slopes will be 1V on 3H. A drainage system will be provided under the stilling basin slab. The spillway piers will be designed to withstand unbalanced water loads caused by having a gate closed with maximum flow in an adjacent bay. The pier thickness will be 10 feet.

138. The stilling basin will consist of a reinforced concrete U-frame. Its length is based on 4d2 (for standard project flood) and will include baffle blocks and an end sill. The length is based on criteria in EM 1110-2-1603. The basin elevation is based on a ratio of theoretical to actual tailwater depth of 1.0 due to uncertainty in the tailwater rating curve.

Outlet Works

139. The low-level outlet works consist of four gate controlled conduits located in the spillway piers. The rectangular conduits are 3 feet wide, 4 feet high, 92 feet long, and will discharge into the spillway stilling basin. The conduits are controlled by slide gates. The design capacity of the outlet works is 1,200

cfs with a headwater elevation of 1596. Details of the outlet works are shown on plate 4.

RENVILLE COUNTY PARK

140. It is proposed to provide 100-year flood protection to Renville County Park with a channel cutoff and left bank levee with tiebacks into high ground upstream and downstream of the park area. A 3,000 gpm pumping station will be provided and the interior channel will provide pond storage capacity. A Texas-type crossing of the cutoff channel is proposed in lieu of a bridge because the park is mainly used during the summer nonflood periods. The crossing will also serve as a control structure for maintaining flows through the interior loop during lower flow periods in summer. At the upstream channel barrier, a stop-log structure is proposed to provide boat access to the river upstream of the park area. The lower barrier would have a 90-inch RCP outlet with gate well. The estimated cost of the protective measures is $1,200,000, including Engineering and Design, and Supervision and Administration. The plan of the proposed work is shown on plate 12. Costs for the Renville County Park were previously included in the costs of Lands and Damages; however, the levee protection costs are now classified as levee costs for the reservoir feature.

McKINNEY CEMETERY

141. The plan for protection of McKinney Cemetery consists of a levee and 24-inch flap-gated outlet. The top of the levee would be at elevation 1609 and it would have an average height of about 5 feet. Other options considered were relocation and raising of the cemetery, but these were not acceptable to local interests. The cost of protecting the cemetery is estimated to be $127,000, including E & D, S & A. Plans for the levee are shown on plate 13. The costs of the levee include provision of a portable pump for removal of interior water during high lake stages. The cemetery costs were previously considered to be a relocation; however, they are now classified as a levee cost in the reservoir feature.

ECKERT RANCH

142. The plan for Eckert Ranch is to provide levee protection from Lake Darling storage and diversion of a tributary drainage area. A stepped drop channel with 2-foot gabion protected drops is proposed. The channel will have a left flank levee to divert flows that pass through the farmyard and cattle feeding area. A pond area will be excavated and a 36-inch flap-gated gravity outlet provided. During floods of longer duration, a portable pump (either tractor mount or submersible) would be required.

Approximately 15 acres would remain tributary to the protected interior area. The estimated cost of protection is $227,000. The ranch was included in the Land and Damages cost estimates in previous studies, but is now classified as a levee cost in the reservoir feature.

REFUGE STRUCTURES

General

143. The structures in both the Upper Souris and J. Clark Salyer National Wildlife Refuges will be modified to ensure their continued functioning and manageability after the raise of Lake Darling Dam. The recommendations for modifications to the structures are based on limited field data. Additional field surveys and testing data will be available for the preparation of the feature design memorandum, at which time the modifications on each structure will be further evaluated. Pertinent data on the refuge structures is provided on table 9 and plans are provided on plates 6 and 15-24. Several meetings have been held with the U.S. Fish and Wildlife Service to discuss the impacts of the project on the refuge structures and on fish and wildlife habitat in general. Further evaluation during preparation of a mitigation report and feature design memorandums is expected to resolve any differences concerning the level of improvements on the structures.

144. The modifications of the refuge structures are separated into operation features and mitigation features, as shown on tables 10-13. Operation features are those structural modifications necessary for the flood control operation of Lake Darling Dam and the continued management of the refuges.

145. The mitigation features are shown, in order of priority in each refuge, as potential measures to offset the adverse project effects on fish and wildlife habitat throughout the Souris Valley. The Fish and Wildlife Service has determined that no additional mitigation lands would be required for the project and that the adverse impacts could be offset by structural improvements to refuge water-control structures, spillways, and dams. (See FWS letter of 4 September 1981 in appendix E.) These measures would provide for more intensive management and increased security for future management in the refuges. The extent of improvements needed to offset habitat losses resulting from the construction and revised operation of Lake Darling Dam is not finalized in this report because the mitigation study and environmental evaluation are not scheduled for completion until May 1984. However, the mitigation items in each refuge are listed in order of priority as determined by the Fish and Wildlife Service. The mitigation study will determine which of those items are justified.

Table 9

Pertinent Data on Refuge Structures

UPPER SOURIS REFUGE

Structure	River Mile	Spillway Length	Spillway Elevation	Top of Gates	Gates	Low Flow	Lowest Embankment Elevation	Embankment Length
41	471.6	1,425'	1596.5	1589.5	1-10'HX12'W (Slide gate)	3'HX6'W	1602.0	500
83 (Lake Darling)	430.0	320'	1598.0	1587.0	2-10'HX12'W	None	1606.0	3,700
87	429.1	700'	1579.1	1578.4	1-8'HX16'W (Tainter gate & 4-13' overflow sections @ elevation 1578.2	4'X4' - Slide gate	1583.5	1,800
96	415.0	700'	1577.3	1577.0	(Same as No. 87 but overflow at elevation 1576.9)	(Same)	1579.6	2,000

J. Clark Salyer Refuge

Structure	River Mile	Spillway Length	Spillway Elevation	Top of Gates	Gates	Low Flow	Lowest Embankment Elevation	Embankment Length
320	194.0	700'	1425.1	1425.6	3-10'HX16'W (Tainter gates)	48" Ø CPM	1428.0	16,000
326	185.5	700'	1421.0	1421.3	3-7'HX16'W	None	1423.6	8,000
332	179.5	700'	1418.5	1417.3	3-9'HX16'W	None	1421.0	5,000
341	171.3	700'	1416.5	1416.3	3-9'HX16'W	None	1419.4	4,000
357	155.5	700'	1414.6	1415.1	3-10'HX16'W	2-24" Ø & 48" stop log in spillway	1418.0	3,000

Upper Souris Refuge Structures

146. In the Upper Souris National Wildlife Refuge, Lake Darling Dam (or dam 83) is the primary refuge structure. The improvements to this structure are discussed elsewhere in the report. The designation of each dam by a number indicates the number of river miles that structure is downstream from the international border (i.e., dam 83 is 83 river miles downstream from Canada). Other major structures in the refuge include dam 41, which is upstream of Lake Darling Dam, and dams 87 and 96, which are downstream of the primary reservoir. Smaller structures, referred to as ponds A, B, and C, are located immediately downstream of Lake Darling Dam. The refuge structures were constructed in the 1930's by what was then the Bureau of Biological Survey, Department of Agriculture. A summary of pertinent dimensions of the Upper Souris Refuge structures is shown on table 9 and plans are provided on plates 6 and 15-19. Dams 41, 87, and 96 consist of low earth embankments across the Souris River flood plain and have gated outlet structures in the river channel and rubble-masonry spillways cut through the embankment sections. Dam 41 has a low-level outlet, located in the Souris River channel, which consists of a reinforced concrete box culvert passing through the embankment and an upstream intake structure with a trashrack and a 10-foot by 12-foot slide gate for flow control.

147. A spillway is located on the west side of the structure. It is about 1,450 feet long and extends across most of the Souris River flood plain. The spillway crest structure was constructed of hand-set rubble masonry with little or no reinforcement. There is a gravel-surfaced road about 20 feet wide upstream of the masonry spillway crest. Releases for refuge management are made through a 3-foot by 6-foot culvert in the spillway. The spillway is silted in on both sides over its full length, and is broken up in several places.

148. The outlets in dams 87 and 96 are essentially the same. Each outlet includes four uncontrolled bays 13 feet long, one gated bay with its top at the same elevation as the weirs in the uncontrolled bays, and a gated low-level outlet. The gated bay is controlled by a radial gate 16 feet wide by 8 feet high. The low-level outlet is controlled by a 4-foot square slide gate. The outlet structures are supported by timber piles. There is a sheet-piling cutoff wall beneath the upstream edge of the structure which extends into the embankment on either side. The spillways at both dams are 700 feet long and are constructed of hand-set rubble masonry with little or no reinforcement.

149. The embankments at both dams 87 and 96 are covered with

grass and brush and both have a significant problem with animal burrows. The concrete at the overflow wall crests is badly deteriorated, as is some of the concrete near the waterline on the piers, both upstream and downstream. There is also uneven settlement of the gated structure at dam 96, which occasionally causes binding in the gates. The radial gates are in satisfactory condidtion. However, the side seals are cracked and the bottom seals are wood instead of rubber. The slide gates have not been inspected because dewatering would be required. The rubble masonry spillways are in good condition; however, there is a heavy grass and brush cover on the crests, and the spillway stoplog section at dam 87 is silted in. The outlet and the spillway capacity (without overtopping the embankment) at dams 87 and 96 are 26,000 cfs and 15,000 cfs, respectively.

150. Measures required in the Upper Souris National Wildlife Refuge for continued operation of the refuge structures after Lake Darling Dam is raised and the revised operating plan is adopted are shown on table 10.

Table 10

Operation Features in the Upper Souris Refuge

	Estimated Cost (1)
1. Upgrade Dam 41 (upgrade spillway at same elevation, improve access from east, actuator on gate).	$1,153,000
2. Raise service roads in reservoir area (elevation 1602).	955,000
3. Provide water supply for pond A (100 cfs).	370,000
4. Provide replacement facility for spillway fishing area.	74,000
5. Raise boat-launch facilities in reservoir elevation 1600 operating level).	51,000

(1) Costs include E & D, S & A

6. Modify fencing for revised service roads.	76,000
7. Provide heaters, actuators, and repaired gates on dams 87 and 96.	325,000
8. Replace outlet from pond A.	20,000
Total Operation Features	$3,024,000

Upgrade Dam 41

151. Because of the relatively low spillway crest elevation of 1596.5, reservoir storage behind the raised Lake Darling Dam will frequently affect the management capability, spillway inundation, and access for gate operation at dam 41. To offset the effects of the higher stages, several modifications to the structure are considered necessary. The spillway would be upgraded with a concrete crest having the same elevation as existing conditions. The 20-foot roadway on the spillway crest would also be upgraded with stabilized aggregate, surface course. The existing outlet would be rehabilitated by having the gate cleaned and painted and installing a power-operated gate hoist. Electrical service would be provided to the gate structure. The 2 1/2-mile segment of township road, which serves as an access road from the east, would be upgraded to offset the reduced access from the west across the spillway.

Raise Service Roads in the Reservoir Area

152. A number of refuge service roads in the reservoir area lie below the design pool elevation of 1605. The frequency and duration of reservoir storage above elevation 1602 does not appear to warrant raises higher than that elevation. Reservoir storage exceeds elevation 1602 about once in 25 years and is above this elevation for less ahan 40 days during a 100-year flood. Therefore, only roads below elevation 1602 would be raised. The service roads are parallel routes on both sides of the valley, and are not continuous. The majority of the sections that would be raised cross tributary drainage areas and, therefore, will require the installation of culverts.

Provide Water Supply For Pond A

153. The existing outlet from Lake Darling will be plugged, and the configuration of the new primary outlet will not permit diversion of water to ponds A, B, and C. A 36-inch bypass with a gated control structure will be constructed near the west abutment of Lake Darling Dam to pond A to permit operation of ponds A, B, and C as under preproject conditions. The capacity of this outlet will be about 50 cfs. The outlet will consist of a con-

crete box intake, a control structure with a slide gate, a concrete pipe conduit through the dam abutment, and an energy dissipator at the point of discharge to pond A.

Replacement Facility for Spillway Fishing Area

154. The recreation area immediately downstream of the Lake Darling spillway will need to be relocated because of the proposed location of the new outlet and spillway. The new site for the recreation area is expected to be further downstream on a peninsula on the east side of the valley. An access road, parking lot, toilet facilty, and a canoe-launch crib would be provided.

Raise Boat Launch Facilities in Reservoir

155. As discussed in the recreation analysis section of this report, the higher reservoir stages will affect several public boat access facilities. Three of the most heavily used ramps would be modified to make them operable at elevation 1600, 2 feet higher than existing conditions. These three ramps are landing 3, Greene Crossing, and Grano Park. Improvements would include earthwork to reshape the existing ramps and raising a portion of the parking lots.

Modify Fencing for Revised Boundaries

156. Any fences affected by revisions of service roads or boundary lines in the refuge, such as for levees or real estate acquistion needs, will be modified with project funds. The cost is based on an estimated 5,000 feet of fence modifications.

Heaters, Actuators and Gate Repairs At Dams 87 and 96

157. Revised operation of Lake Darling Dam will require the capability to pass larger flows through the refuge structures in early spring because of the reservoir drawdown schedule. Current procedures for opening the gates in the spring involve time consuming, manual labor for removal of ice, repair of any gate damage caused by ice, and use of a portable actuator for gate operation. To ensure the ability of the structures to pass releases from Lake Darling earlier in the spring or at other times when Lake Darling releases are changed, heaters, actuators (or motorized hoists), and repair of the radial gates are viewed as a project requirement.

158. All outlet structure gates would be removed and taken to a shop for sandblasting and cleaning. The side seal assemblies, bottom seals, trunnion hubs, guide roller, and hoist cables would be replaced. The gates would be painted and re-installed. Heating tubes would be installed on the skin plates of the radial

gates, and the side seal and bottom seal plates in the concrete outlet structures would be replaced with ones containing conduits for heating fluid. Electrically powered heating system modules would be located near the gates on dam crests. These modules heat a water-antifreeze mixture and circulate it to the gates using small pumps.

159. The existing gate hoists would be replaced with motorized ones. An electrical supply would be required at each of the gated outlet structures to operate the heating system and the motorized hoists.

Replace Outlet from Pond A

160. A stop-log structure located immediately downstream of the existing outlet at Lake Darling Dam would be removed because of the flattened downstream slope on the raised Lake Darling Dam. The stop-log structure is used to maintain the desired water level in pond A. Flows through the structure pass directly to the main channel of the Souris River. A replacement outlet to the main channel would be provided at the downstream end of pond A in the location of an existing spillway. This spillway has a severe seepage problem and will, therefore, be removed and replaced by a 30-inch outlet by a control gate.

161. Measures in the Upper Souris Refuge that are viewed as potential mitigation for habitat losses caused by the revised operating plan are shown on table 11, in order of priority as determined by the Fish and Wildlife Service. The mitigation study, which is scheduled for completion by May 1984, will identify those items on the mitigation list which are required to compensate for habitat losses.

Table 11

Mitigation Features in Upper Souris Refuge

	Estimated Cost (1)
1. Provide low-flow outlet between pool A and pool B	$ 11,000
2. Upgrade dam 96	757,000
3. Upgrade gated structure dam 87	257,000

(1) Costs include E&D, S&A

4. Provide bypass at dam 87 to downstream impoundment	100,000
5. Raise spillway at dam 87 1 foot, rehab embankment, and restore marsh	821,000
6. Upgrade dikes A, B, and C	359,000
7. Upgrade downstream trails	136,000
Total	$2,441,000

162. Because the extent of mitigation needs for the Lake Darling project is not defined at this time, it is not known whether any, some, or all of the items in table 11 would be required to offset habitat losses. If there is need for mitigation, the highest priority structural improvement in the Upper Souris Refuge would be the replacement of the outlet between pools A and B.

163. The separation of structural improvements for mitigation purposes between the Upper Souris Refuge and the J. Clark Salyer Refuge will be defined in later studies. However, any habitat losses occurring in a refuge will be mitigated by structural improvements in that same refuge. The determination of which refuge receives which structural improvements for habitat losses occurring elsewhere in the valley will be defined in later studies.

Provide Low-Flow Outlet Between Pool A and Pool B

164. An existing 30-inch outlet would be replaced by a reinforced concrete structure (with a slide gate) of hydraulic capacity similar to that of the existing structure. The existing outlet is in poor condition and its replacement would ensure future operation capabilities for maximum management potential in these refuge pools.

Upgrade Dam 96

165. As previously discussed, the outlet structure at dam 96 is in need of major repair. There is uneven settlement and serious deterioration of concrete on the structure. For this reason, the upgrading of dam 96 is a high priority mitigation measure in the Upper Souris Refuge. The entire gated structure at dam 96 would be replaced. The new structure would have a low-flow slide gate and two radial gates 16 feet wide by 8 feet high instead of the existing single gate of the same dimensions. The additional gate would replace the existing overflow weirs that have a total length of 52 feet, 0.4 foot lower than the spillway crest. The

recommended configuration would provide larger discharge capacity through the outlet and would therefore allow more flexible operation. The operational work discussed earlier, which included gate repairs, heaters, and actuators, would not be required as a separate cost at those sites where the gated structure is being replaced as a mitigation feature, but the cost of these measures would be deducted from the mitigation costs. The rubble masonry spillway would be replaced with a concrete structure. The earth embankment at dam 96 would be rehabilitated to eliminate the animal burrows that presently cause leakage problems. The upstream and downstream embankment slopes and the spillway will be stabilized using riprap, and stabilized aggregate would be added to the crest where needed.

Upgrade Dam 87

166. Dam 87 is generally in better condition than dam 96. However, it will be replaced if measures beyond the upgrading of dam 96 are required for mitigation. The new structure would be similar in design to dam 96; however, it may be located slightly downstream of the existing gated structure for easier construction and better access. No upgrading of the spillway or embankment would be included.

Provide Bypass at Dam 87 to Downstream Impoundment

167. An existing waterfowl management pond could be more intensively managed if it had an additional supply of water. The normal headwater elevation upstream of dam 87 is 1578, and the desired water level in the downstream impoundment is 1577. The mitigation feature would provide a 48-inch reinforced concrete pipe 400 feet long around the west side of the gated structure and a 2,400-foot-long earth channel to the pond. Concrete endwalls would be constructed upstream and downstream of the conduit and the flow would be controlled by stop logs.

Raise Spillway at Dam 87 1 Foot, Rehab Embankment, Restore Marsh

168. To provide more intensive management capabilities in the pool created by dam 87, 1 foot would be added to the spillway crest elevation. The existing rubble masonry spillway would be replaced with a concrete structure. The earth embankment would be rehabilitated to eliminate the animal burrows that presently cause leakage problems. Riprap would be placed on portions of the embankment that are susceptible to erosion, and stabilized aggregate would be added to the crest where needed.

Upgrade Dikes A, B, and C

169. The dikes surrounding ponds A, B, and C will stabilized by flattening the slopes to 1V on 5H and establishing a vegetative cover. Riprap will be placed on slopes where wave action is expected to be a problem.

Upgrade Downstream Trails

170. Service roads and trails that are in need of repair would be upgraded as a mitigation feature. Any fill required for raising the roads would be taken from the immediate area, such as from ditch excavation, and stabilized aggregate would be hauled from other sources. An estimated 10 miles of roads would be upgraded.

J. Clark Salyer Refuge Structures

171. There are five major structures in the J. Clark Salyer National Wildlife Refuge: dams 320, 326, 332, 341, and 357. These five low-head dams which form the waterfowl management ponds in the Salyer Refuge were constructed in the 1930's by what was then the Bureau of Biological Survey, U.S. Department of Agriculture, and are all essentially the same design configuration. Each dam consists of a low earthen dike across the Souris River flood plain, a gated outlet structure constructed in the river channel, and an ungated spillway in the dike section.

172. The gated outlet structures consist of three 16-foot-wide rectangular channel sections constructed of reinforced concrete. Manually operated radial gates control the discharge through the outlet. The ungated spillways are constructed of hand-set rubble masonry, with little or no reinforcement. Reinforced concrete buttresses have been constructed on the downstream side of the crests and at the endwalls. A concrete cap beam has been placed at the downstream edge of the spillway crests, except at dam 357. A summary of the pertinent dimensions of the Salyer Refuge dams is shown in table 9, and plans are provided on plates 20 to 24.

173. A number of repair and improvement projects have been completed in the 50 years since the dams were constructed, including:

a. Capping and buttressing the weir and endwall sections of the ungated spillways, as noted above.

b. Raising the channel walls and gate hoisting equipment at the gated outlet structures.

c. Repairing and/or replacing flood damaged spillway and embankment sections.

d. Adding low-flow outlets to discharge water for use in refuge management programs.

e. Reinforcing and extending wingwalls at dam 357 using steel sheet-piling.

174. Several inspections and stability computations have been made of the refuge structures for this study, with the following observations:

a. Embankments: The Fish and Wildlife Service indicated that there have been no problems with seepage through the embankments. Problems with animal burrows have only been minor in the Salyer Refuge, but the Fish and Wildlife Service expects the problem to increase when refuge pools are held at higher stages for longer durations. Most of the embankments were originally dragline cast. There is erosion and sloughing in certain reaches of the embankments, especially where they are unprotected from wave action.

b. Spillways: The field inspection indicated that the rehabilitated rubble masonry crest walls with concrete cap beams appear to be stable against overturning and sliding. However, if the rubble masonry at the downstream apron is eroded or undermined, an unstable condition may result. Most of the earth berms upstream of the crest structures are badly rutted.

c. Gated outlets: The appearance of the concrete is generally good. There are some minor shrinkage cracks on the pier and abutment faces. A preliminary stability analysis was made, and the results indicate that the structures are stable under the assumed normal operation and flood conditions.

d. Gates: All of the existing manual hoists are moving freely, with no sticking or binding detected. Most of the hoist wire ropes are rusted. All of the side seals are cracked and some are damaged. The guide rollers, two on each side of each gate, cannot be turned. The trunnion assemblies are badly rusted. The bottom seals on the gates are wood, not rubber. The side seal plates, which are embedded in the concrete structures, extended only to the top of the gates in their closed position.

175. Hydraulic routings were made of various discharges, such as the 600 cfs and 800 cfs profiles shown on plate 20, to determine effects of the revised reservoir operation. Measures required in the J. Clark Salyer National Wildlife Refuge for continued operation of the refuge structures after the revised Lake Darling operating plan is adopted are shown on table 12.

Table 12

Operation Features in J. Clark Salyer Refuge

	Estimated (1) Cost
1. Provide carp control velocity barrier for large flows and electric weir for low flows	$ 600,000
2. Provide heaters, actuators, and repaired gates on all five structures	1,030,000
3. Raise service roads, scenic trails, boat and canoe launch and exit sites	300,000
Total	$1,930,000

(1) Costs include E & D, S & A.

176. Carp control. Carp are not found in the North Dakota portion of the Souris River, but have been found in the lower Souris River near its confluence with the Assiniboine River in Canada. If carp migrate upstream into the wildlife refuge areas, they will reduce the availability of food for fish and fowl. Carp are bottom feeders and have a tendency to make water muddy and to destroy aquatic plants.

177. It cannot be definitely shown at this time that the changes in flows which will result from operation of the Lake Darling project will increase the risk of carp migration from the Assiniboine River upstream on the Souris River to the National Wildlife Refuges in North Dakota. Reports indicate that the dam at Wawanesa, Manitoba, serves as a barrier to upstream carp migration. However, carp have been seen upstream of the Wawanesa Dam following springs of high river discharges. Insufficient year-round flows is considered to be the primary reason that carp have not survived and migrated into the United States portion of the Souris River. However, extended higher releases associated with the recommended operating plan might provide adequate conditions for carp migration further upstream. Therefore, until more detailed study can be completed, costs for a carp control structure will be included in the project costs.

178. Successful control of carp migration requires that the control facilities be totally effective, making year-round protection necessary. Carp migrations are most likely to occur during late spring and early summer, when high-flow conditions prevail. Many physical screening systems exist; however, practical problems, such as the large volume and areal extent of the streamflow and trash and ice buildup, would make the costs of a successful screening system prohibitive.

179. The method which has the highest potential to protect against migration is a velocity barrier. Carp have specific swimming abilities and the velocity against which they can swim for a given duration can be computed on the basis of their length. This velocity, translated into the ability to move a specific distance through a channel, is the basis for the suggested design.

180. The design length for the carp was assumed to be 3.5 feet, which substantially exceeds the size of carp found in the Souris River. The velocity barrier will be developed by confining the flow through the outlet works and over the spillway by earth embankments to a trapezoidal channel which will cause the expected summer discharge (500 cfs) to pass through at a velocity of about 5 feet per second, well in excess of the minimum velocity required to block carp movement.

181. For flows below 500 cfs, electric screening by means of a fixed flat-plat electrode is suggested. The plates would be anchored to and insulated from a concrete slab across the velocity-barrier channel. Once installed, very little maintenance would be needed. A stand-by generator would be required. The Wisconsin Department of Natural Resources reports good success in controlling carp migration for flows up to 700 cfs.

182. The velocity barrier would consist of two levees 12 feet high with a total length of about 4,000 feet. The embankment requirement is 240,000 cubic yards, and slope protection on the river side would be accomplished with 12 inches of riprap totalling 4,000 cubic yards.

183. The first cost of electric screening by a fixed-plate electrode would be about $80,000. This cost includes installation of the electrode and a stand-by generator. The annual operating cost is estimated to be about $8,000.

184. Heaters, actuators, gate repairs. Revised operation of Lake Darling Dam will require the capability to pass larger flows through the refuge structures in early spring because of the reservoir drawdown schedule. Current procedures for opening the gates in the spring involve time consuming manual labor for removal of ice, repair of any gate damage caused by ice, and manual operation of screw-type hoists on the gates. To ensure the ability of the structures to pass releases from Lake Darling earlier in the spring or at other times when Lake Darling releases are changed, heaters, actuators (or motorized hoists), and repair of the radial gates are viewed as a project requirement.

185. All outlet structure gates would be removed and taken to a shop for sandblasting, cleaning, and straightening of skin plates, horizontal girders, and radial arms. The side seal assemblies would be replaced and the wooden bottom seal would be replaced with rubber seals. Guide rollers would be replaced with guide lugs and trunnion hubs would be replaced. The gates would be painted and re-installed. Heating tubes would be installed on the skin plates of the radial gates and the side seal and bottom seal plates in the concrete outlet structures would be replaced with ones containing conduits for heating fluid. Electrically powered heating system modules would be located near the gates on the dam crests. These modules heat a water-antifreeze mixture and circulate it to the gates using small pumps.

186. The existing gate hoists would be replaced with motorized ones and the hoist wire rope would be replaced. An electrical supply would be required at each of the five gated outlet structures to operate the heating system and the motorized gate hoists.

187. Raise service roads, scenic trails, boat- and canoe-launch and exit sites. These facilities in pool 320 are affected by prolonged releases of 500 cfs from Lake Darling Dam. The mitigation work would involve raising the service roads, trails, and other facilities a maximum of 3 feet by use of fill materials available in the immediate area of each facility. Stabilized aggregate for the road surfaces would be hauled from other sources.

188. Measures in the J. Clark Salyer Refuge that are viewed as potential mitigation for habitat losses caused by the revised operating plan are shown on table 13 in order of priority as determined by the Fish and Wildlife Service. The mitigation study, which is scheduled for completion by May 1984, will identify those items on the mitigation list which are required to compensate for habitat losses.

Table 13

Mitigation Features in J. Clark Salyer Refuge

	Estimated Cost (1)
1. Construct potholes in wet meadow areas	$ 147,000
2. Upgrade dam 320 with spillway and top of gates 2 feet higher	2,423,000
3. Upgrade dam 326 with spillway and top of gates 2 feet higher	1,094,000
4. Upgrade dam 332 with spillway and top of gates 2 feet higher	898,000
5. Upgrade dam 341 with spillway and top of gates 2 feet higher	740,000
6. Upgrade dam 357	819,000
7. Add low-flow structures at dam 320 for improved circulation	28,000
8. Add low-flow structure at dam 326 for improved circulation	28,000
Total	$ 6,177,000

(1) Costs include E & D, S & A.

189. Potholes in wet meadows. The proposed potholes would be constructed within the J. Clark Salyer Refuge upstream of dam 320. Approximately 20 potholes, ranging in size from ½ to 1 acre and 3 to 4 feet deep, and having 1 vertical to 10 horizontal side slopes, would be excavated. The excavated material would be hauled from the area.

190. Upgrade dams (with spillway and top of gates 2 feet higher). Because the extent of mitigation needs for the Lake Darling project is not defined at this time, it is not known whether any, some, or all of the refuge structures need to be upgraded to offset habitat losses. If there is need for mitigation beyond the construction of the potholes discussed above, all upgrading work would be done first on dam 320, the highest priority structure. Work at other structures would follow in the order shown on table 13, and the number of structures upgraded would depend on the magnitude of mitigation needs.

191. The work at each site would include removing the existing gated structure and replacing it with one of similar configuration, except that the top of gates would be 2 feet higher. The operational work discussed earlier, which includes gate repairs, heaters and actuators, would not be required as a separate cost at those sites where the gated structure is being replaced as a mitigation feature, but the cost of these measures would be deducted from the mitigation costs. The spillway would be replaced with a concrete structure having a crest elevation 2 feet higher than existing conditions. The additional 2 feet of storage at each dam allows for more flexible management in terms of vegetation control and water quality. Department of Interior criteria require the top of embankments to be 3 feet above the spillway crest; therefore, the embankments would be raised to comply with this standard. With flattened slopes, the embankments would also be better protected from erosion caused by overtopping and wave action. The 1V on 7H slopes would be protected with topsoil and seeding. The work at all the sites would be similar, except at dam 357, where no raise is considered necessary.

192. Low-flow structures at dams 320 and 326. If the mitigation needs exceed the upgrading of all five refuge structures, low-flow outlets would be provided at dams 320 and 326 to improve water circulation. The low-flow outlets would be 48-inch reinforced concrete pipes with slide gates.

DOWNSTREAM URBAN LEVEES

193. To minimize adverse environmental and social effects in the reservoir area and to provide a reasonable degree of Souris River control, the proposed reservoir operating plan provides for releasing at a maximum rate of 5,000 cfs at Minot. To accommodate this release rate, levee improvements are proposed for subdivision areas between Burlington and Minot and at Sawyer and Velva, as shown on plates 25 to 33.

194. Between Burlington and Minot, there are six subdivision areas with levees constructed by the Corps of Engineers during the 1970 flood emergency and upgraded during subsequent flood emergencies. In 1976, the levees were capable of passing 9,300 cfs. The situation is similar at Sawyer and Velva.

195. The existing levees are typical emergency levees, having steep (1V on 1H to 1V on 2H) side slopes, a narrow top width in places, and no significant erosion protection. Although clearing of the levee foundation was done for the initial construction, grubbing and stripping of the foundation and excavation of an inspection trench were not done. During the initial construction and subsequent raises, there was no significant control on fill placement and compaction of the fill was limited to that which could reasonably be obtained with the hauling and spreading equipment. Raises were done by simply placing fill on top of the levee and allowing it to spill over the side slopes and around or over existing vegetation.

196. Although these emergency levees have protected the communities during past floods, it should not be assumed that they provide any level of permanent protection. Protection during past floods was successful only because the levees were constantly patrolled and significant remedial work was done at critical locations to prevent failures. There are some reaches of these levees that would not come close to satisfying any reasonable geotechnical design criteria for permanent levee protection.

197. As decided at the 13 April 1982 Issue-Resolution meeting (MFR in appendix E), the appropriate level of permanent flood protection for the downstream levee areas would accommodate the 5,000 cfs reservoir releases. If the levee protection is economically justified as a second, in-place unit to the raise of Lake Darling Dam, the protection should be increased to provide maximum net benefits. The costs for the levee protection would be borne by the Federal government, and local interests would be responsible for lands, rights-of-way, and relocations. Any costs for a level of protection higher than that necessary to pass the 5,000 cfs discharge plus local inflow, if the levee system is not incrementally justified, would be entirely a local responsibility.

198. A range of channel modifications and levee heights and alignments was considered in previous Burlington Dam studies. Channel cutoffs were investigated for Velva, Sawyer, King's Court, and Brook's Addition. Only the cutoff at Velva was shown to be cost effective. Generally, levee alignments were laid out to closely follow the alignments of existing emergency levees. Preliminary hydraulic and cost studies indicated that channel modifications to reduce flood stages (thereby decreasing required levee heights) would not be as cost effective as providing higher levees. This conclusion appears reasonable because the slope of the Souris River channel is extremely flat and the leveed areas are small in size and are not contiguous. The conclusions of previous studies were used for comparison of alternatives; therefore, the recommended designs are based on studies performed in 1977. As shown on table 14, evacuation was evaluated as an alternative to structural flood protection at each of the communities studied. In each case, the recommended levee alternative was more cost effective than evacuation, except at Brook's Addition. The method of flood control at this subdivision will be studied further in the feature design memorandum or as a value engineer study.

199. Table 14 also shows the cost benefit-cost ratio, design discharge, and degree of protection for each of the leveed areas. Only Velva has a benefit-cost ratio over 1.0 for the 5,000 cfs reservoir releases; therefore, the level of protection for that community is 14,700 cfs. Additional supporting data and design details on the Velva levee system are provided in a previously submitted feature design memorandum, (DM No. 4, November 1982) and are not repeated in this report. Additional hydraulic considerations for the design of the other leveed areas are presented in appendix A of this report. As shown on table 14, a 100-year discharge was routed through the leveed areas to determine the additional levee height required for this level of protection. However,

TABLE 14

DOWNSTREAM URBAN LEVEES

	Johnson's Add.	Brook's Add.	Talbott's Nurs.	Country Club	King's Court	Tierr. Vallejo	Total Burl.-Minot	Sawyer	Velva
Costs ($1,000)									
Channels	10	128	---	100	114	28	380	302	2,567
Levees	271	422	89	539	402	178	1,921	302	1,335
Emb.	(156)	(349)	(33)	(378)	(201)	(92)	(1,209)	(237)	(341)
Int. Drain	(115)	(93)	(56)	(161)	(201)	(86)	(712)	(65)	(994)
Pumping	160	160	149	163	153	176	961	---	207
E & D	54	92	31	101	83	46	407	36	420
S & A	28	48	16	54	44	24	214	20	301
S & I	(20)	(34)	(11.5)	(38)	(31)	(17)	(151.5)	(14)	(185)
O.H.	(8)	(14)	(4.5)	(16)	(13)	(7)	(62.5)	(6)	(116)
Total Federal	523	870	285	957	796	452	3,883	358	4,830
Lands & Damages	250	190	300	230	150	140	1,260	130	269
Payment	(220)	(150)	(280)	(170)	(90)	(100)	(1,010)	(90)	(221)
Acquist.	(30)	(40)	(20)	(60)	(60)	(40)	(250)	(40)	(48)
Relocations	6	6	13	21	18	---	64	11	67
Total Non-Federal	256	196	313	251	168	140	1,324	141	336
Grand Total	779	1,066	598	1,208	964	592	5,207	499	5,166
Average Annual Costs	43.8	60.7	33.1	68.7	55.0	33.5	294.9	32.7	280.3
Average Annual Benefits(1)	22.0	6.5	4.7	62.7	38.9	2.0	136.8	--- (2)	285.8
B/C Ratio	0.50	0.11	0.14	0.91	0.71	0.06	0.46	--- (2)	1.02
Design Discharge (cfs)	5,000	5,000	5,000	5,000	5,000	5,000		5,500	14,700
Frequency of Exceedence (w/Raise of Lake Darling Dam-years)	27	27	27	27	27	25		22	100
Additional Levee Height required to achieve 100-year protection (feet)	6	5	5	5	4	3		3	0
Alternative Cost of Evacuation	$1,800,000	$500,000	$1,200,000	$5,700,000	$2,200,000	$1,300,000		$2,800,000	$16,000,000

(1) Benefits are shown in 1983 prices. These figures have been updated from the Benefit section of the report using the 1983 Urban Update Factor of 1.043 used in the budget update for FY 1985.

(2) Preliminary hydraulic routings performed for this study show no benefits for levee protection at 5,000 cfs reservoir releases; however, levees will be assumed to be required until a more refined hydraulic model is developed in later studies.

because the 5,000 cfs designs are not economically justified, the costs for 100-year protection were not determined. Hydraulic routing for this study shows that there are only minimal damages at Sawyer for the 5,000 cfs reservoir release rate plus 25-year local inflow. However, levees for the city will continue to be recommended as a project feature and further analysis of the need for levee protection at 5,500 cfs flows will be performed for the feature design memorandum.

200. In the Burlington to Minot reach, 5.4 miles of levees in six intermittent levee systems would be upgraded to meet current engineering standards for foundation stability and interior drainage. The emergency levees would be realigned and regraded as necessary to pass a flow of 5,000 cfs, plus up to 3 feet of freeboard. In places where the levees are constructed between the channel and adjacent development, the channel would be realigned to permit proper design of levee slopes. Riprapping would be included where necessary to prevent erosion of the channel and the riverward slope of the levees. The permanent plan of protection also includes the provision of six pumping stations, ponding areas, and interceptor ditches and conduits, as necessary.

201. The levee construction at Sawyer and Velva would be similar to that in the Burlington to Minot reach except that the levees would be upgraded to pass a flow of 5,500 and 14,700 cfs, respectively.

202. The top width of most of the earth levees will be 10 feet and the riverward and landward slopes will be 1V on 3H. Most of the material required to provide proper slopes and grades for the permanent levees can be obtained from the existing emergency levee fill. Levee tops, landward slopes, and a portion of the riverward slopes will be covered with topsoil and seeded to provide an aesthetically pleasing and easily maintained structure.

203. Channel modifications will be provided where the structures to be protected are close to the river banks. Channel cut slopes will vary from 1V on 2.5H to 1V on 3H. Channel bottom widths will vary from 40 to 50 feet. Channel bottom elevations for realigned reaches will be the same as existing elevations. Proposed levee and channel improvements are summarized in table 15.

Table 15

Downstream Urban Levees - Levees and Channels

Area	Area protected by levee (acres)	Length of levees (feet)	Average elevation of levee crest (ft, msl)	Average height (feet)	Channel improvement length (feet)
Burlington to Minot					
Johnson's Addition	73	4,500	1,574	5	300
Brook's Addition	49	4,785	1,573	5	1,350
Talbott's Nursery	11	2,650	1,572	3	---
Country Club Acres and Robinwood Estates	110	7,180	1,570	5	780
King's Court and Rostad's Addition	25	4,030	1,569	4	1,210
Tierrecita Vallejo	33	5,115	1,561	4	690
Sawyer	43	4,225	1,526	5	---
Velva	339	9,950	1,516	6	3,270

Table 16

Downstream Urban Levees - Interior Drainage Facilities

Area	Contributing drainage area	Gravity outlet diameter	Pumping station capacity	Length of interceptor sewer	Gate closure elev.
Burlington to Minot					
Johnson's Addition	103	24	3,000	---	1,565.5
Brook's Addition	325	36	3,000	---	1,567.0
Talbott's Nursery	38	24	3,000	---	1,563.5
Country Club Acres and Robinwood Estates	132	24	3,000	---	1,561.0
King's Court and Rostad's Addition	27	24	3,000	1,565	1,560.0
Tierrecita Vallejo	33	2 - 24	3,000	---	1,557.0
Sawyer	65	24	---	---	1,512.0
Velva	1,900	2 - 90 Twin 48 2 - 36 2 - 24	6,800	3,870	1,501.0

204. Major interior flood control facilities include gated gravity outlets, permanent pumping facilities, temporary ponding areas, and intercepting storm sewers. The gravity outlets and storm sewers would be reinforced concrete pipe, and the gate structures would consist of a gate well with a sluice gate.

205. Interior flood control facilities were designed on a preliminary basis using standard hydrologic and hydraulic design criteria. Contributing interior drainage areas, potential gravity outlet locations, pumping station sites, storm sewer locations, and ponding areas were identified from field reconnaissance, previous studies of the leveed areas, and topographic maps. Gravity outlets and storm sewers were sized to pass the one-percent storm runoff without significant interior flood damages. Pumping stations were sized to prevent serious interior flood damages during periods of high Souris River levels. Hypothetical rainfall data was obtained from technical publications. River hydrographs were developed using Horton's method. Damage-elevation data were estimated for each leveed area, based on field reconnaissance and standard damage computations. Elevation-area-capacity data for each ponding area were estimated from available tographic maps.

DOWNSTREAM RURAL MEASURES

General. In addition to the six subdivision areas between Burlington

and Minot and the communities of Sawyer and Velva, there are rural areas downstream of the reservoir affected by the Lake Darling Dam operating plan. An aggregate economic evaluation was made of various downstream reaches to determine if there are net adverse impacts to ownerships as a result of the revised reservoir releases. Based on the results of these economic studies, one of four basic actions could take place on a particular downstream ownership:

1) Changed conditions due to the project result in a net adverse effect on the total ownership which has a residence in the affected area. This requires an interest (flowage easements) to be taken on the property and the residence acquired.

2) Changed conditions due to the project result in a net adverse effect on the total ownership which does not have a residence in the affected area. This requires an interest (flowage easement) to be taken on the property with no buildings acquired.

3) Changed conditions due to the project result in net benefits on the total ownership, but the residence or access to the residence is flooded at 5,000 cfs controlled reservoir releases. This requires providing the option for the property owner to have the residence flood proofed and access road raised, or residence acquired if it is the only solution. The property owner may choose to take no action.

4) Changed conditions due to the project result in net benefits on the total ownership and the residence and access are not affected by 5,000 cfs controlled reservoir releases. This requires no action taken.

206. This analysis was based on a sampling of typical ownerships in various reaches and not on each individual ownership. A more detailed analysis is to be performed in later studies to define the actual impact on each ownership. However, until such an analysis is performed, the results of this economic evaluation should represent the approximate magnitude of the impacts on downstream landowners, while not defining the actual ownerships that are affected.

207. The general evaluation shows that of the 40,000 acres flooded by 5,000 cfs downstream of the reservoir (Plates 34-45), there are approximately 570 acres adversely affected and approximately 12 residences that would need to be acquired since they are located on a flowage easement area. These 570 acres of flowage easements and acquisition of 12 residences are therefore the current estimates of the acquisitions as defined in the first and second basic actions shown above. Owners that are adversely affected would not have an option on acquisition. From this analysis, the balance of the 40,000 acres is shown to be benefited from project operation and no acquisition would be required. Where acquisition is required, it is the responsibility of the local interests. Occupants of any acquired residence would be eligible for relocation benefits under Public Law 91-646. The property owner would receive a fair market value for the residence and could then elect to retain the structure for salvage value and relocate it to higher ground at his own expense.

208. There is estimated to be an additional 100 farm and non-farm rural residences that are affected by 5,000 cfs reservoir releases as summarized above as the third basic action. When considering the total property associated with these residences, the preliminary analysis indicates that there are overall net benefits on each of these ownerships and therefore no measures to protect the residences from the planned reservoir releases are required. Because there is not a net adverse impact on an individual property as a result of the project, there is no need to take an interest in that property. However, without flood protection, these residences would remain subject to flooding from reservoir controlled releases and local inflow contributions.

209. Accordingly, the proposed plan includes protection of these rural dwellings by a combination of measures including levees encircling indivdual residences; flood proofing, including raising of residences and access roads; installation of holding tanks to temporarily handle sanitary wastes; and flood proofing of wells. Where levees and flood proofing would not be feasible, residences would be purchased and property owners would have the option to relocate to high ground. The plan would not include protection of farm buildings, silos, or any other improvements outside the place of residence.

210. The least costly of the alternative measures that adequately provide flood protection could be implemented at the option of the individuals involved. The property owner could choose to do nothing or could select a more expensive method of flood protection, with the incremental cost at the property owner's expense. Implementation of the structural measures such as construction of levees, raising the residences and access roads, and modification of sewer and water facilities would be accomplished with Federal funds. Acquisition of homes for relocation and any easement or right-of-way costs would be the responsibility of the local sponsor. The justification for downstream measures to protect residential structures is based on mitigation of social impacts and the fact that most areas will receive a net benefit from the project.

211. Besides the structural and non-structural flood protection measures being implemented downstream of the reservoir, the items of local cooperation include the provision that the local sponsor provide guidance and leadership in preventing unwise future development of the flood plain. It is recommended that flood plain regulations be adopted in the residential flood plain to preclude future development.

LOCAL PROTECTION FROM GASSMAN COULEE

212. Gassman Coulee has three principal branches which join and form a confluence with the Souris River 3 river miles upstream from Minot. The coulee has a drainage area of only 35 square miles; however, its potential for causing flooding in the Souris Valley upstream of Minot and in the city of Minot is significant because of its location and the steepness of its drainage area. The gradient of the coulee

averages 25 feet per mile. The Governor of North Dakota has expressed concern over the flood threat from Gassman Coulee. A flood from the Gassman Coulee has not been recorded; however, a standard project rainstorm centered over the coulee could cause an estimated 10,000 cfs dischard at Minot. In earlier studies, it was determined that a dam on the coulee lacked economic feasibility. The recommended plan includes an automated flood warning system on Gassman Coulee which would reduce the threat to loss of life and the high economic losses in Minot and adjacent developments.

213. The recommended flood warning system would consist of the following components:

Remote data stations:	2 precipitation gages and 2 stream gages with data encoders
Central master station:	1 minicomputer
Remote alarm station:	1 microcomputer

214. One remote data station, including a precipitation gage and a stream gage, will be installed in an upland portion of the watershed on the middle branch of Gassman Coulee. The principal function of this station is to provide advance warning of possible floods. The remaining precipitation gage and stream gage will be located in a lower portion of the watershed near the mouth of Gassman Coulee. The lower gages will provide advance verification of flood hazard conditions. The lower stream gage will also record flood stages.

215. Each remote unit will include a data sensor, encoder, transmitter, and a power supply. In addition, the downstream gage will contain a recorder unit. Each remote data station operates as an electrical switch. A change in status, such as the tipping of a rain gage bucket or a rise in water level, activates the electrical components of the system. Pertinent information (i.e., incremental depth of precipitation or rise of water level) is reduced to a coded electrical impulse. This information, along with station identification, is transmitted by radio to the central master station. Date of transmission, remote station identification, and the data are logged by the central master station. The master station will also perform the pertinent analysis which provides advance warning of flood hazard.

216. The master station will consist of a minicomputer and a radio transceiver. It will receive, translate, and log encoded data; make simple data tranformations, such as river stage to discharge; compare rates of change and absolute data values with alarm threshold values; and transmit and record alarm messages. The central master station is proposed to be located in Minot.

217. On the basis of data transmissions from the remote data stations, the central master station will derive answers to the following questions:

a. Is rainfall of sufficient depth and intensity to activate a low-level flood alert?

b. Will the estimated flood, when combined with current Souris River flows at Minot, exceed channel capacity and cause flooding?

c. Do water-level transmissions verify the flood status posed by information received from the precipitation gages?

218. Three levels of alert, based on the number of affirmative answers to the above questions, will be activated by the central master station. Alert warning will be logged by the data-output system and will be automatically transmitted to Minot police headquarters. If subsequent tranmissions from the remote data stations indicate a decrease in flood hazard, the central master station will automatically rescind low-level warnings.

219. The logic by which the central master station analyzes flood status is based upon calibrated models of rainfall-derived floods. Several such models have already been conducted for Gassman Coulee by the Corps of Engineers. Threshold levels for rainfall intensity and depth will be obtained from a thorough review of the existing models.

220. Precipitation data will be calibrated to recorded discharge of Gassman Coulee during the initial operating period of the system. Inherent in the proposed system is its adaptability to unanticipated changes of logic systems, threshold flood values, model coefficients, etc. Changes of precipitation or discharge threshold values will be entered in the central master station by simple computer programming procedures.

221. The remote alarm station will consist of a microcomputer and radio receiver located in police or fire headquarters in Minot. Its objective will be to receive alert warnings processed and transmitted by the central master station.

222. Component and annual operating costs of the proposed system are $280.000 (including E & D, S & A), and $6,000, respectively.

RELOCATIONS

ROAD RELOCATIONS

State Highway 5

223. North Dakota State Highway 5, which crosses the Souris River in Renville County, is a major route and is part of the national defense network. The highway will be raised from elevation 1604.8 to elevation 1607.5. The

bridge deck will be raised 1.5 feet from elevation 1609.0 to elevation 1610.5. The bridge will also be lengthened by adding two 50-foot spans to one side. This will require the removal of one existing bridge abutment, construction of two new bridge piers and one new bridge abutment, and construction of the two new 50-foot spans. Plate 8 shows the plan layout, including the proposed raised and lengthened bridge. The total estimated cost for the Highway 5 alterations is $1,513,000, including E & D, S & A.

Grano Crossing (FAS 3828)

224. Grano Crossing (FAS 3828) crosses Lake Darling near Grano in Renville County. The present Grano Crossing elevation of 1602.4 will be raised to 1607. The existing bridge will be raised 4 feet 1 inch so that low steel is at elevation 1605.5 and the top of the bridge deck is at elevation 1608.5. Plate 10 shows the proposed plan. The total estimated cost for the alteration is $2,280,000, including E & D, S & A.

State Highway 28

225. North Dakota State Highway 28 is a major route which crosses Lake Darling in Ward County approximately 7 miles downstream of Highway 5. The highway will be widened and raised 1.5 feet to elevation 1607. The existing seven-span timber bridge is in fair-to-poor condition and is closed to loads greater than 10 tons. The bridge will be removed and replaced with a new three-span, 180-foot-long prestressed concrete box girder bridge supported by 12-inch-diameter steel encased concrete piles. Plate 9 shows the plan layout of the proposed alteration. All improvements comply with North Dakota Class A highway standards. The total estimated cost for the highway bridge modification is $2,036,000, including E & D, S & A.

Renville County Road 9

226. During operation of the raised Lake Darling Dam, Renville County Road 9 would occasionally experience higher water levels. Although the bridge section appears stable for uplifting and debris loads, the approaches may be subjected to erosion. Therefore, riprap and bedding will be placed on the embankment slopes. The estimated cost for stabilizing Renville County Road 9 is $107,000, including E & D, S & A.

Bridge Over Lake Darling Dam Spillway

227. The proposed bridge over the Lake Darling Dam spillway is shown on plate 4. The top of deck would be at elevation 1614.5 and would have a width of 30 feet inside the curbs. The bridge would be supported by the spillway piers, which are positioned 53 feet on center. As shown on plates 2 and 3, the road across the Lake Darling Dam embankment would be 24 feet wide and have 8-foot shoulders. Approach roads would be raised, and the upgraded roadways would be paved with 3 1/2-inch bituminous surface. The cost of raising the approach roads and constructing a bridge over the spillway at Lake Darling Dam is $1,137,000, including E & D, S & A.

SOO LINE RAILROAD

228. The Soo Line Railroad crossing near Greene, North Dakota, has a minimum elevation of 1605.8 at the top of the rail. The earth-fill embankment has stone protection, a 300-foot wood trestle bridge, and a single-line track with ballast and ties as shown on plate 11.

229. Preliminary results of analysis and discussion with Soo Line Railroad Company officials indicated that a raise of the top of the track to elevation 1608 would be the recommended relocation measure. The work would include:

a. a new embankment adjacent to the existing embankment

b. an excavated channel and a bridge located in the right abutment

c. new track, ties and ballast

d. switching system to allow use of the track during construction.

230. The recommended plan would decrease the frequency of inundation from once in 30 years (under dam-raise conditions) to once in 500 years, a frequency similar to existing conditions. Approximately 1.1 miles of track will be replaced. Layouts showing existing and proposed replacement structures are shown on plate 11. The cost of raising the Soo Line track would be $6,236,000, including E & D, S & A.

Temporary Routing of Traffic

231. Two structures planned for raising. Soo Line railroad track and State Highway 5, would pass traffic during construction. Raising State Highway 28, Grano Crossing, and Lake Darling Dam will require the use of temporary detour routes. Also, there would be some minor disruption of traffic during construction at Renville County Road 9, dam 41 spillway, and the diversion weir at Renville County Park. A list of detour routes and distances is shown on table 17.

Table 17

Summary of Detour Routes

Road	Detour route	Additional distance of detour (miles)
Highway 28	Grano Crossing, 2 unnamed roads	9
Grano Crossing	State Hwy. 28, 2 unnamed roads	10
Lake Darling Dam	Baker Bridge (Ward Co. Rd. 8), 2 unnamed roads	12

UTILITY RELOCATIONS

232. Preliminary alteration/relocation plans were developed for telephone and power companies which own facilities within the proposed Lake Darling Reservoir and along roads which are to be upgraded. Approximately 3.8 miles of underground line and 0.7 mile of overhead line are planned for abandonment or removal. In addition, 8.2 miles of new distribution lines will be constructed. A water supply system in Renville County will be flood proofed or modified, as necessary, to make it operable with reservoir storage. Relocation/alteration plans were developed so that service would be maintained for all facilities that cross the Souris River Valley. The estimated cost of all alterations and relocations of utilities is $151,000. Summaries of the relocation/alteration plan for each utility company and the respective cost estimates are listed in table 18.

Table 18

Utility Relocations

Utility	Proposed action	Cost
Montana-Dakota Utilities Co.	Remove 0.7 mile of existing 41.6 KV overhead line and construct 0.9 mile of 41.6 KV transmission cable. Provide 2.8 miles of new underground electric distribution facilities	$78,000
Souris River Telephone Mutual Aid Corporation Minot, N.D.	Abandon 3.8 miles of underground cable line, construct 4.5 miles of underground cable line, and reinforce 1.9 miles with waterproof cable.	$ 65,000
Renville County Water System	Flood proof or modify sites	$ 28,000
	Total cost (with E & D, S & A)	$171,000

CONSTRUCTION PROCEDURE AND DIVERSION PLAN

LAKE DARLING DAM

233. The following preliminary construction sequence has been developed for modification of Lake Darling Dam. The existing secondary spillway on the right abutment will be enlarged and concrete and sheetpile crest protection installed. This will allow flow to be diverted through the secondary spillway and the existing low-flow outlet while the new control is being built on the left abutment. Following modification of the secondary spillway, the primary spillway will be cofferdammed off to permit construction of the new control structure and as much of the new

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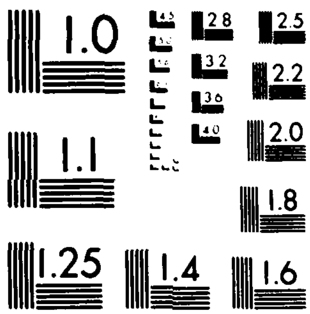


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

discharge channel as practical. Material excavated for the new spillway and discharge channel will be used to complete the required embankment modifications to the maximum extent practical. When the new control structure is completed, the downstream cofferdam will be removed and the discharge channel completed. The upstream cofferdam will then be removed and the approach channel completed. The new control structure will then be operational and diversion will no longer be required. A cellular sheetpile cofferdam will be installed around the upstream end of the existing low-flow structure, the structure excavated, removed, and the excavation backfilled. Removal of the cellular cofferdam and completion of the embankment and right abutment approach roads can then be done. It is anticipated that highway traffic across the dam will be maintained to the maximum practical extent. Texas crossings will be installed on the secondary spillway and traffic routed across the upstream cofferdam while the new control structure is being built. Closure of the road will obviously be required whenever flow occurs over the secondary spillway and for removal of the existing low-flow structure. Occasional road closures may also be required for construction purposes.

ROAD RELOCATIONS

State Highway No. 5

234. Modifications to the bridge will not require diversion of the river, but a traffic detour around the bridge will be required. Present plans are to detour traffic over an older Highway 5 bridge just upstream of the present bridge. By raising one-half of the embankment at a time and detouring traffic around the present bridge while the modifications are being done, one lane can be provided for traffic during construction.

State Highway 28 and Grano Crossing

234a. The State Highway 28 bridge will be replaced with a new bridge at the same location, and the deck of the existing FAS Route 3828 bridge will be raised. This work will not require diversion of the river, but traffic detours will be required. Present plans are to close these valley crossings to traffic while bridge and embankment construction is being done. Traffic will be rerouted over alternate highways. Because of the proximity of these two highways, one can be used as a detour for the other. Consequently, modification of these two highways will not be scheduled simultaneously.

SOO LINE RAILROAD

235. The existing track will remain in service while the new bridge on the right abutment and the embankment across Lake Darling are constructed. When the new bridge is completed, the track will be routed over it and the bridge approach and discharge channels completed. The old bridge will then be removed, backfilled with earth fill, and the track placed over the new embankment.

ENVIRONMENTAL ANALYSIS

236. The existing environmental conditions in the Souris River Valley upstream of Verendrye are that of a small stream in an oversized valley. The valley floor is an average of three quarters of a mile wide and lies 100 to 200 feet below the ground-moraine plain. The valley walls are fairly steep. Downstream of Verendrye, the river valley is in the glacial Lake Souris area, is one-half to 3 miles wide, and is relatively flat. Two U.S. Fish and Wildlife Service (FWS) national wildlife refuges, Upper Souris and J. Clark Salyer, impound extensive reaches of the upper and lower Souris loop, respectively. The FWS-owned Lake Darling Dam is located in the Upper Souris National Wildlife Refuge and forms the major impoundment on the Souris River. The primary function of Lake Darling is to supply water to downstream impoundments in both refuges, but it has also been operated to provide some flood storage during spring runoff on the Souris River.

237. Agriculture is the primary business in the Souris basin, and there are many small farming communities in the area. Minot is located near the midpoint of the Souris loop and is the region's major center for commerce, manufacturing, and services.

238. Land use trends, including floodplain development and both legal and illegal wetland drainage, have apparently contributed to the floodplain problems in the area. Wetland drainage reduces flood storage capacity in the basin and increases runoff into the river and its tributaries.

239. The Souris River floodplain forest comprises about 2 percent of North Dakota's forests. This constitutes a significant resource in a State which ranks 50th in the country in total forest acreage.

240. The two national wildlife refuges on the Souris River, along with other wetlands in the basin, contribute an important percentage of the State's total annual waterfowl production. The diversity of habitat along the Souris River also supports numerous other wildlife species.

241. Population in the Souris basin is unevenly distributed among the seven counties:

	1980 Population
Bottineau County	9,388
Burke County	3,822
McHenry County	7,858
(includes city of Velva 1,101)	
Mountrail County	7,679

Pierce County	6,166
Renville County	3,608
Ward County	58,392
(includes city of Minot 32,843)	

242. Each county's population declined between 1970 and 1980, and the region experienced an overall decrease of 3.5 percent. Although united as the Souris Basin Planning Council (North Dakota Region II), these counties do not yet function in a unified way for water resource management. Each county maintains separate water management districts and independent taxing and regulating authorities.

SIGNIFICANT RESOURCES

243. Project impacts on the study area's significant natural and human resources are discussed below. A resource can be judged to be "significant" on the basis of any of these criteria: (1) the resource has been identified in the laws, regulations, guidelines, or other institutional standards of national, state, and local public agencies or private organizations; (2) the resource meets certain study-specific technical criteria for measuring characteristics that may be critical to resource existence, such as scarcity, vulnerability, resiliency, or tolerance; and (3) the resource has been identified as a concern by the general public.

244. These discussions are a general overview of potential impacts identified in previous studies of Souris River flood control. A more detailed analysis of project impacts on affected resources will be included in the Lake Darling site-specific EIS. Environmental impacts of the Velva levee feature are discussed in the Velva Flood Control Feature Environmental Impact Statement. Table 18a shows the impacts of the various features or feature alternatives on significant resources. Recreational resources are discussed separately in the Recreation Analysis.

WATER QUALITY

245. The State of North Dakota has classified the Souris River as a 1A stream, which means it is suitable for the propagation of resident fish species, for boating and swimming, and for irrigation, stock watering, and wildlife use. Municipal use would require treatment to meet bacteriological and chemical standards. The river generally has low flows during the fall and winter. Non-point source pollution and occasional discharges from municipal sewage lagoons contribute to the marginal water quality of the Souris River.

246. Lake Darling has been classified as a 2C cool water fishery (suitable for non-salmonid fish species). The lake is somewhat eutrophic and is progressing toward further degradation because

Table [illegible]a-Comparative Impacts of Alternatives and Features (Continued)

Plan features and alternatives / Significant Resources	Cultural Resources	Recreational Resources	Aesthetics	Institutional Arrangements	Social Cohesion	Transportation
Base Condition	12 known archeological sites 8 historic sites (1 on National Register of Historic Places) above Lake Darling. 18 known archeological sites 6 historic sites adjacent to Lake Darling	Refuge landings day-use areas, 2 county parks, several minor recreation areas and informal rec. use sites at bridge crossings within study area.	Souris River Valley contains a variety of landscape, vegetation, and wildlife, providing important scenic qualities in the basin	Somewhat constrained financial capacity; low formal coordination between water resource/political organizations; some formal planning documents and mechanisms available.	History of conflict related to an earlier flood control proposal, a compromise plan has been developed by various groups and individuals.	Road network basically adequate and usually well maintained.
No Action (Without-Project)	Existing impacts would continue	Existing impacts would continue	May decline because of wetland drainage.	Gradually worsening financial capacity at local govt. levels, coordination unlikely to increase without greater State pressure, gradual increase in floodplain/land use management.	No predictable changes	No change in network, but gradually increasing maintenance problems
Pool Raise to 1605 Operation Plan: 5000 ft³/s discharge to normal pool level	Increase in number of sites impacted because of increased duration of inundation, and erosion potential.	Partial loss of rec. use days - minor damage to some recreation resources	Fluctuating water levels in Lake Darling could kill or damage shoreline vegetation, causing denuded condition; increased duration of flooding downstream could adversely affect aesthetics of riparian areas	Strain on financial capacity, increasing organizational complexity and interdependence among governmental units, stimulus to more conscious planning and coordination	Uncertain acceptability of project details (see below)	No effect
Pool Raise to 1605, Operation Plan: 5000 ft³/s discharge [illegible] 15,500 ft³/s to normal pool or [illegible] [illegible] 700 ft³/s to [illegible]ession	See above	Loss of early season recreation use, major adverse impact on spring fishing access; partial damage of recreation resources	See above	Same	Uncertain acceptability of project details (see below)	No effect
Renville Co. Park Acquisition/Relocation	Adverse impact on historic structures from removal.	Adverse impact on regional recreational resources.	Relocation site would not likely be as attractive as present site.	Same	Uncertain acceptability of alternatives for Renville County Park	No effect
Floodproofing	Adverse impact on historic structures from floodproofing	Loss of recreational use days during construction for camping and some day-use activities.	Floodproofed structures could be less attractive.	Same	Same	No effect
Levee and Channel Cutoff	Beneficial impact on historic structures	would provide protection for recreational resources and maintain existing use levels.	Losses of riparian vegetation could result in less attractive surroundings.	Same	Same	No effect
McKinney Cemetery Relocation	Adverse impact on NRHP property.	No effect	Effect would depend on relocation site	Same	Uncertain acceptability of alternatives for McKinney Cemetery protection	No effect
Raise in Place	Minimal impact on NRHP property	No effect	Short-term adverse effect.	Same	Same	No effect
Levee Protection	Minimal impact on NRHP property.	No effect	Possible adverse effect.	Same	Same	No effect
Downstream Rural Protection Acquisition/Relocation	May remove some potentially historic structures.	No effect	Effect would depend on individual case.	Same	Uncertain acceptability of alternatives for downstream rural flood protection.	Some disruptions to traffic during construction.
Floodproofing	May alter some potentially historic structures.	No effect	Floodproofed structures could be less attractive.	Same		
Levees, Dikes	May adversely affect unknown archeological resources.	No effect	Possible adverse effect.	Same		
Levees at Sawyer and Six Subdivisions	May have adverse effect on historical and archeological properties	No effect	Losses of riparian vegetation would result in less aesthetically pleasing surrounding.	Same	Uncertain acceptability of levee alternatives.	Some disruptions to traffic during construction.
Modify Upper Souris Refuge Structures	Modification of dam 41 could affect 2 sites; work on ponds A or B could impact 1 site not eligible for NRHP.	Minor impact on refuge recreation sites; limited impact on rec. use days.	Negligible	Same	Same	Same
					Same	Same
Eckert Ranch Acquisition/Relocation	Will have adverse effect on historic properties.	No effect	Effect would depend on relocation site.	Same	No effect	No effect
Levees/Dikes	Will have beneficial effect on historic properties.	No effect	Possible adverse effect	Same	No effect	No effect
Gassman Coulee No Action	Existing impacts on NRHP properties in Minot would continue	No effect	No effect	Same	No effect	No effect
Flood Warning System	May have beneficial effect on NRHP properties in Minot.	No effect	No effect	Same	No effect	No effect
Road and Rail Raises	Soo Line RR raise and Hwy 28 raise could impact known sites; Hwy [illegible]5 and Cty. Rd. [illegible] possible impact.	Minor adverse impact on existing rec. use.	Effect would depend on individual perceptions.	Same	No effect	Some disruptions to traffic during construction; deterioration to be repaired at completion of work

Table 19—Comparative Impacts of Alternatives and Featu es

Plan features and alternatives \ Significant Resources	Water Quality	Aquatic Resources	Wildlife Resources	Vegetation	Renville Co. Park	[illegible] Cemetery
Base condition	Souris River is a class 1A at [illegible]. Lake Darling is a class 2C la [illegible] eutrophic.	Souris River is carp-free in North Dakota, has a diversity of other fish species. Lake Darling has a good quality northern pike and walleye fishery.	Upper Souris and J. Clark Salyer National Wildlife Refuges are significant water fowl production areas, river valley contains diverse wildlife habitat.	There are about 7,950 acres of Souris River floodplain forest and 300,000 acres of wetlands in Souris basin, 15% of Souris' floodplain is grassland; there are about 11,000 acres of agricultural land in affected floodplain.	5 permanent county buildings, 70 summer homes, about 5 permanent residents, 70-acre site at 1606 msl, day and overnight county owned and operated park.	A National Register of Historic *Places property*.
No Action (without-Project)	Souris River will continue to suffer from both point and non-point source pollution problems. L[illegible] Darling will continue trend toward eutrophy	Aquatic habitats would continue to suffer from chronic water pollution problems; winter-kill may recur in Lake Darling and J. Clark Salyer Refuge.	Losses of wetland habitat due to drainage will likely continue in the basin.	Continued drainage of wetlands in the basin; agricultural acreage will increase.	Existing impacts would continue.	Existing impacts would continue.
Pool Raise to 1605, [illegible] Plan 5000 ft³/s discharge [illegible] pool level	Some increase in sedimentation in Lake Darling. Extended discharges could increase river bank erosion downstream. No significant changes in overall water qua[illegible]ty are foreseen	Short-term sedimentation impacts during construction; Lake Darling drawdowns could increase chances of winter kills. Extended discharges could have both beneficial and adverse effects on aquatic habitat downstream.	Extended discharges would delay marsh level management in refuges and adversely affect downstream riparian habitats; water level fluctuations in Lake Darling could adversely affect shoreline habitat.	Water level fluctuations in Lake Darling could adversely affect floodplain forests, wetlands, grasslands, and agricultural lands. Extended discharges would have both beneficial and adverse effects on downstream vegetation; 11,000 acres downstream ag. lands could be flooded 2 weeks longer than present condition.	Stage and duration would increase impacts on historic structures over existing conditions, flood damages to rec. facilities, loss of rec. use days.	Stage and duration would increase impacts on NRHP properties over existing conditions.
Pool raise to 1605, Operation Plan. 5000 ft³/s discharge to 5 [illegible] 500 ft³/s to normal pool or 9/1 then 700 ft³/s to recession	See above	See above	Similar to above; effects on marsh level management could be worse.	See above	Stage and duration would greatly increase impacts on historic structures over existing conditions and other operating plan.	Stage and duration would greatly increase impacts on historic structures over existing conditions and other operating plan.
Renville Co. Park Acquisition/Relocation	Possible minor improvement if relocation is out of floodplain.	Possible minor improvement if relocation is out of floodplain.	Minor improvement depending on relocation site.	If structures were removed, site could revert to natural state; loss of vegetation at relocation site.	See Cultural and Recreational Resources and Social Cohesion.	No effect
[illegible]proofing	Some improvement from sewage system upgrading.	Minor improvement from sewage system upgrading	No effect	No effect	Same	No effect
[illegible] and channel [illegible]	Same	Same	Minor losses of habitat.	Some clearing during construction.	Same	No effect
[illegible] Cemetery [illegible]ation	No effect	No effect	Minor long-term increase in available habitat.	Site could revert to natural state; loss of vegetation at relocation site.	No effect	See Cultural Resources and Social Cohesion.
[illegible] in place	Negligible	Negligible	Negligible	Negligible	No effect	Same
[illegible] protection	Possible short-term increase in turbidity during construction.	Possible short-term minor impact during construction.	Minor loss of habitat.	Minor clearing for levee construction.	No effect	Same
Downstream Rural Protection Acquisition/Relocation	Possible minor improvement in some cases.	Possible minor improvement in some cases.	Negligible	Negligible	No effect	No effect
Floodproofing	No effect.	No effect	No effect	No effect	No effect	No effect
Levees, dikes	Possible short-term increases in turbidity during construction.	Possible short-term adverse effects during construction.	Negligible	Negligible	No effect	No effect
Levees at Sawyer and Six Subdivisions	Short-term increases in turbidity during construction. Some adverse effects due to losses of riparian cover.	Short-term adverse effects during construction; some decline in habitat quality possible.	Decreases in habitat quantity and quality due to clearing.	Some clearing of floodplain forests; some losses of other vegetation types.	No effect	No effect
Modify Upper Souris Refuge Structures	Short-term construction impacts.	Disruption of habitats in individual impoundments and downstream during construction.	Disruption of habitat during construction; long-term benefits to refuge management objectives.	Disruption of managed marshes during construction; minor impacts on other vegetation during construction.	No effect	No effect
Eckert Ranch Acquisition/Relocation	Long-term minor improvement possible.	Long-term minor improvements possible.	Effect would depend on relocation site.	Some losses of vegetation at relocation site.	No effect	No effect
Levees/dikes	Possible short-term increases in turbidity during construction.	Possible short-term adverse effects during construction.	Minor losses of habitat.	Minor losses from clearing.	No effect	No effect
Gassman Coulee No Action	No effect	No effect.	No effect	No effect	No effect	No effect
Flood Warning System	*No effect*	*No effect*	*No effect*	*No effect*	No effect	No effect
Road and Rail Raises	Short-term construction impacts.	Short-term construction impacts.	Short-term disruption of habitat during construction.	Minor vegetation removals during construction.	No effect	No effect

it traps nutrients.

247. Water quality impacts would include short-term increases in turbidity during construction of project features. Holding Lake Darling at elevation 1598 for prolonged periods of time, coupled with periodic inundation at higher elevations, would increase erosion and sedimentation in the reservoir. Although the sedimentation increase is not expected to be large, it could result in increased nutrient loading from ions adsorbed on the sediments, which could aggravate the already eutrophic conditions. The reservoir would continue to dilute dissolved salts, settle out suspended solids, and act as a nutrient "sink," reducing nutrient loads downstream. Although the erosive effects of existing peak flood flows would be reduced, long-term release rates at higher than normal flows would exert steady erosive forces at higher bank elevations than under existing conditions. Higher flows should decrease water temperatures and increase the level of dissolved oxygen. Project features at Eckert Ranch would reduce feedlot runoff into Lake Darling.

AQUATIC RESOURCES

248. The Souris River is carp-free in North Dakota and contains a diversity of other fish species. In its 1978 Permanent Stream Evaluation, the U.S. Fish and Wildlife Service gave the Souris River the highest fishery resource rating. However, some reaches of the river experience winterkills because of low flows and impaired water quality.

249. Lake Darling has a high quality sport fishery but is limited by increasing eutrophication and related algae blooms, siltation, occasional winterkills, and reservoir drawdowns for flood control.

250. Short-term impacts on the aquatic ecosystem in the Souris Valley would result from project construction activities, including dam construction, modification of refuge impoundments, proposed Velva levee and cutoff construction, and levee construction at other project sites. These impacts would result from direct physical disruption and, more importantly, from increases in suspended sediments that would bury aquatic invertebrates, irritate exposed membranes of fish and invertebrates (possibly to the extent that secondary bacterial infections could occur), and reduce light penetration. Northern pike and yellow perch spawning habitat in the lake may be improved by a raise in elevation of the reservoir for flood storage.

251. During years of extended releases following flood storage, higher than normal flows in the Souris River would have both positive and negative effects on the aquatic ecosystem. The erosive effects of existing peak flood flows would be reduced;

however, higher summer and possibly fall releases (depending on the operating plan and the severity of the flood) could exert a constant erosive force on the riverbanks at higher than normal elevations. The river could become more turbid and carry a higher silt load, which could cover or scour spawning sites and reduce the quality of aquatic habitat. On the other hand, higher flows could improve fish habitat that is currently limited by normal low summer flows.

252. An analysis will be conducted to determine if carp, presently confined to the lower Souris River downstream of Wawanesa Dam, would be able to migrate up through the Souris loop as a result of the project. This is a prominent concern because of the adverse impact carp have on waterfowl habitat. The proposed plan includes provision for carp control measures if the results of the analysis indicate they are needed. These measures consist of a high-flow/high-velocity channel and a low-flow electric wier at Fish and Wildlife Service dam 357 to prevent carp from migrating upstream.

WILDLIFE RESOURCES

253. The two Souris River national wildlife refuges contain the most valuable wildlife habitat along the river and are important environmental concerns related to the proposed project. The primary purposes of the Upper Souris NWR are production of huntable waterfowl, provision of other necessities in the life cycle of waterfowl, and water supply to J. Clark Salyer NWR (through assured releases from Lake Darling). The refuge also provides habitat for upland and big game, furbearers, and nongame species; winter cover for deer from the surrounding area; public use of refuge-related resources; some haying and grazing; and prevention of waterfowl depredations on private lands. There is also a significant amount of big game hunting on the refuge. J. Clark Salyer NWR, which is larger than the Upper Souris NWR, has similar purposes and uses, except for the water supply function. Both of these refuges serve as vitally important, dependable waterfowl habitat reserves during drought years.

254. The most significant impacts on wildlife resources would result from prolonged discharge flows for flood storage evacuation from Lake Darling. This would hinder current marsh management practices downstream from the dam, especially in the J. Clark Salyer Refuge. Flexibility in raising or lowering pool levels to achieve various refuge management objectives is critical to the success of waterfowl production and other wildlife management goals. Because flows greater than 250 cfs restrict the drawdown capability (according to the Fish and Wildlife Service) in the Salyer Refuge, an operating plan consisting of a 500 cfs discharge over the summer would be detrimental to marsh management.

255. Water level fluctuations in the Lake Darling flood pool would cause changes in shoreline emergent vegetation, floodplain forest, grassland, and agricultural land. The most significant impacts would occur in the marshes and bottomland forests at the north end of the lake. There would be displacements of animal populations during flood storage, and the quality of habitat for certain species could be seriously reduced.

256. Downstream riparian habitat could be inundated for several weeks or for the entire summer and into fall, depending on the operating plan selected and the severity of the flood. Prolonged inundation could kill certain plant species, altering the composition of the biotic community. In addition, inundated habitat would normally be providing important life requisites such as breeding, nesting, and feeding cover.

VEGETATION

257. The floodplain forest along the Souris loop is an important ecological community because it represents 2 percent of North Dakota's total forest acreage. As wetland drainage continues in the Souris basin, those wetlands owned and managed for wildlife purposes are becoming increasingly important as the focus of available waterfowl habitat. Natural and impounded floodplain wetlands in the two national wildlife refuges must be intensively managed to maximize their potential habitat value in the face of the increasing wetland losses.

258. About 15 percent of the Souris floodplain consists of grassland acreage, which is important for grazing and wildlife habitat. About 30 percent of the floodplain is in agricultural use for both haylands and croplands.

259. Water level fluctuations in Lake Darling could adversely affect all of its vegetative community types. The severity of impacts would depend on the severity and timing of the flood, the degree of drawdown prior to the flood, the character of the underlying soils, the species composition and life stage of the vegetation, the frequency of flood storage from year to year, and topography. Extended discharges downstream of the dam would have both beneficial and adverse effects on vegetation, depending on the tolerance of the species. About 38,000 acres would be flooded by 5,000 cfs releases. Of that, 11,000 acres are agricultural land, 5,000 acres are forested, 15,000 acres are wetlands, and about 7,000 acres are grassland (including some shrublands).

260. At a 500 cfs discharge, management of wetlands and haylands in the J. Clark Salyer National Wildlife Refuge would be hampered because of difficulty in draining individual pools. In addition,

about 1,800 acres of private hayland upstream of the refuge would be affected at 500 cfs discharge. Construction would also affect vegetation through clearing and covering with levee fill.

SOCIAL RESOURCES

261. The following resources addressed by Section 122 of the River and Harbor Flood Control Act of 1970 (P.L. 91-611) would be significantly affected by the proposed project.

Institutional Arrangement

262. The basin's social, economic, and political life exists within a framework of legal and habitual arrangements between various organizations and individuals. Three aspects of these institutional arrangements are particularly important for this project: the financial capacity of the revenue system, the network of organizational relationships, and the existing plans for the region and its component areas.

a. Financial capacity is governed by the tax bases and legal limitations of different taxing authorities at the local levels. The State Water Commission would require a specific legislative appropriation before it could provide substantial assistance on the project. Financial capacity at the State and local levels may become increasingly limited if national and regional economic trends continue. Energy resource development in the State and world agricultural demand may offset this trend, however.

b. Organizational relations are currently not highly coordinated for water resource management, and one group's policies and actions often contradict another's. Recent North Dakota laws encourage appropriate changes, such as floodplain management and basin-wide water resource districts. A coalition (some of whose members are also members of affected political units) has laid the groundwork for a compromise among the different interests, who were earlier unable to reach a consensus on the Burlington Dam project. Organizational relations are unlikely to change significantly without outside influence.

c. Plans relevant to this project include those objectives and goals of the Souris Basin Planning Council, such comprehensive plans as exist in the region, zoning and land use ordinances, and State policies and plans. Plans in the region will gradually include more participation in the Federal flood insurance program and more conscious land use guidance. Water resource management will probably continue to be fragmented.

263. A joint water resource board is being organized under the

leadership of the Ward County Resource District. Under State law, such a joint board would have 4 mills levying capacity. This mill rate would not be adequate to pay for local costs if these costs are eventually determined at the Army's proposed 35 percent local share. Under this proposed formula, the individual units of local government would not be able to finance the project. The joint board might combine with the cities and, if they secure at least a $4 million contribution from the State, they would be able to finance the local share.

Social Cohesion

264. Social cohesion exists in the Souris basin, as elsewhere, among people or groups when there are shared values, interests, and experiences; when neighborhood safety and stability are assured; and when social and political arrangements are perceived as equitable. Cohesion can be disrupted by a failure in these factors and by controversy over specific issues; the earlier conflict over the proposed Burlington Dam was an example of the region's normal cohesiveness being fragmented into opposing interest groups. Although there will occasionally be sources of conflict in the region, including anxiety and anger over continued flooding, there is no reason to predict a long-term change in the level of social cohesion. However, while the present project is the result of local political compromises, it has not yet been tested by a larger public opinion. The effect on social cohesion is therefore uncertain. Specific areas of concern include McKinney Cemetery, Renville County Park, perceptions of equity between upstream and downstream interests, and acquisition of homes or property.

Transportation

265. Roads and railroads are important links for the cities and farms scattered over the region. Although usually well-maintained, the roads often lack satisfactory alternate routes, particularly in the case of the infrequent bridges over rivers and lakes. The road network will probably remain much the same, with possible maintenance problems if the local tax base becomes less secure. Several roads crossing Lake Darling may have to be raised, causing as yet undetermined disruption to traffic. Local roads will bear heavy loads during several construction seasons, causing temporary deterioration. The roads will be restored by the Federal contractors.

266. The potential exists for significant impacts in the following other areas: displacement of people, desirable community growth, health, land use, institutional relationships, man-made resources, natural resources, and air and water quality.

CULTURAL RESOURCES

267. In compliance with Section 106 of the National Historic Preservation Act, as amended, the National Register of Historic Places has been consulted. As of 29 June 1982, only one property on the Register, McKinney Cemetery (listed in 1978), would be affected by the raise of Lake Darling or by the downstream levee and channel work.

268. Archeological and historical surveys of the project area were conducted in 1978 by the University of North Dakota. The historic survey was conducted in an area from the Canadian border south to the Des Lacs-Souris confluence. The archeological survey was conducted in the same area but was much less intensive upstream of Lake Darling. Currently, additional studies are being done to survey the downstream levee and channel work and those areas above Lake Darling that were not covered in the 1978 survey. Also included in this ongoing work is the initiation of a testing program to determine if known sites and those discovered during the present survey are eligible for the National Register of Historic Places. The results of these investigations and the detailed impact assessment will be presented in the site-specific EIS to be prepared later.

McKinney Cemetery

269. The McKinney Cemetery was established in the 1880's and includes the gravesites of many of the area's pioneers. Although the cemetery was originally associated with the former townsite of McKinney, it is still being used by the local residents. This property has been placed on the National Register of Historic Places because of its age and significance to local history. The social and historical impacts of alternatives to protect, raise, or relocate a portion or all of the cemetery will be discussed in greater detail in the site-specific EIS for Lake Darling. Relocation or a raise of the cemetery would have adverse impacts upon the site. Section 106 coordination (Public Law 89-665) has been initiated with the State Historic Preservation Office, which has indicated that construction of a levee would be the most favorable alternative.

Renville County Memorial Park

270. Renville County Park is potentially eligible for the National Register of Historic Places. Acquisition or flood proofing would have an adverse impact upon this resource, while protection of the park by levee construction would have a beneficial effect. Most of the 70-acre site lies approximately at elevation 1600 and would therefore be subject to flooding by the proposed raise in Lake Darling pool elevation. Levee protection is currently viewed as the most favorable alternative for flood protec-

tion because it would protect both the privately-owned and county recreation structures on the site. Archeological surveys are currently underway to determine impacts on this resource.

271. Under the no-action plan, archeological and historical sites upstream and adjacent to Lake Darling would continue to be inundated. A pool raise to 1605 and discharge of 5,000 cfs to normal pool level would inundate a larger number of cultural resources for a longer period of time. Marginal sites could be affected by erosion and wave action.

272. An operating plan that would discharge 5,000 cfs until 15 May and then greatly reduce discharge during summer months would increase the number of sites presently inundated. Inundation of some sites could extend from spring to fall. Marginal sites could be greatly affected by erosion and wave action.

273. Downstream historic structures would be the most likely cultural resources to be affected by acquisition, relocation, or flood proofing. Small ring levees around these structures could affect archeological sites. Overall impacts may be a trade-off between archeological and historic resources. Cultural resources investigations for this feature will not be undertaken until the summer of 1983.

274. A Gassman Coulee flood warning system could have beneficial effects upon National Register properties within Minot. Acquisition of the Eckert Ranch would adversely effect the Parker Log House, which is potentially eligible for the National Register.

275. Construction of levees at Sawyer and six subdivisions between Burlington and Minot could affect archeological and historic resources. A cultural resources survey of these proposed levees was completed in the fall of 1982.

276. Three archeological sites could be adversely affected by the work to be done at Fish and Wildlife Service dam 41 and at pools A and B below Lake Darling Dam. One archeological site could be affected by the raise of the Soo Line railroad bridge, while an additional site could be affected by the Highway 28 bridge raise. Presently unknown resources could be affected by work at the Highway 5 and Renville County Road 9 bridges.

AESTHETIC VALUES

277. Increased flood storage could subject elevations of the Lake Darling shoreline between the conservation pool and the flood pool to inundation and subsequent recession of floodwaters. This could produce areas of dead vegetation and mudflats. Although the effects of peak flooding would be reduced downstream of the dam, extended releases of between 500 and 5,000 cfs for

varying lengths of time could kill some inundated vegetation and subject some areas to long-term erosive forces. The effect on aesthetics of this area would be adverse until recovery takes place.

RECREATION ANALYSIS

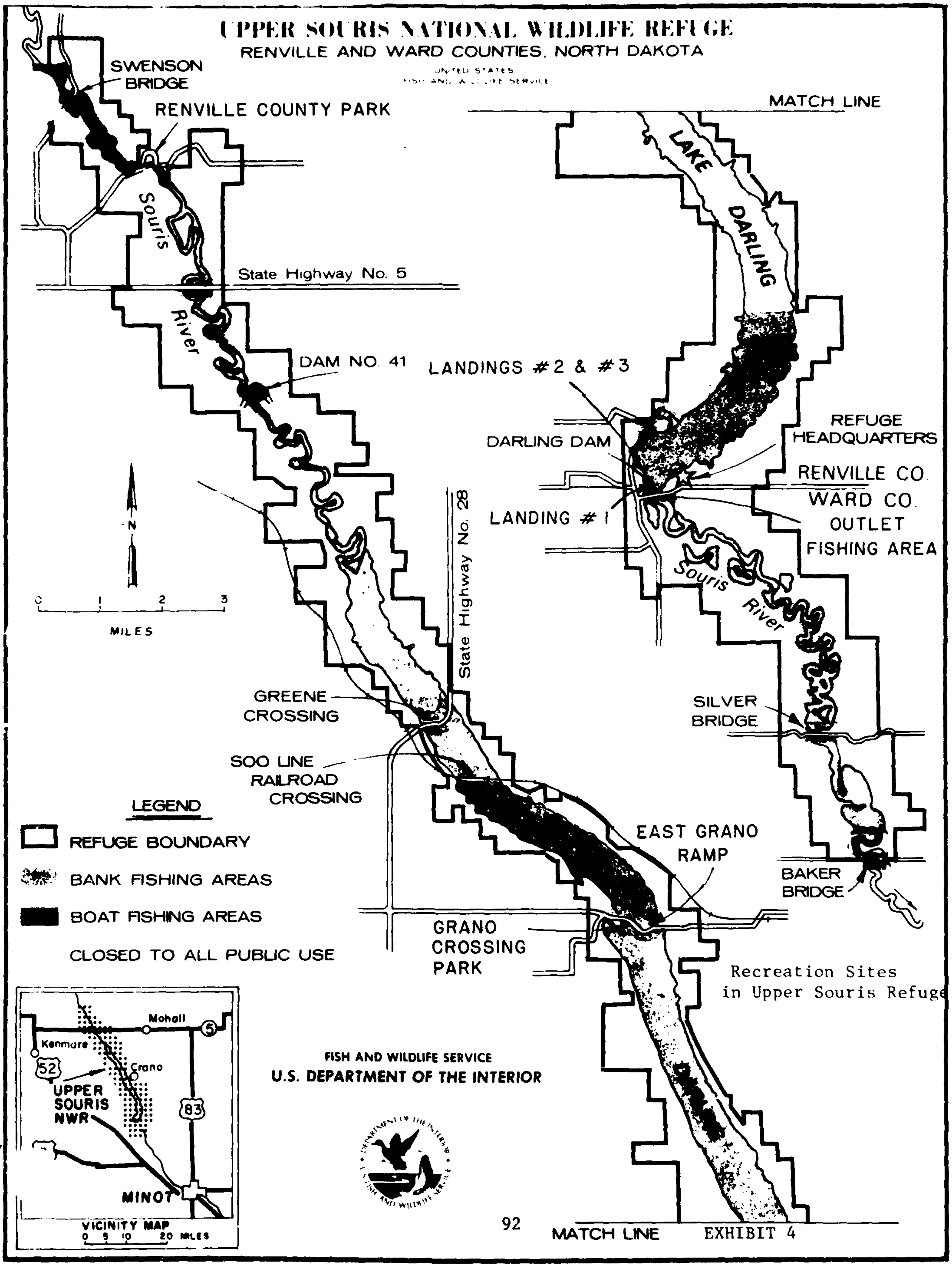
INTRODUCTION

278. This recreation analysis is limited to a brief description of existing recreation sites within the Lake Darling project area. The proposed project does not include any new recreation facilities except those required to mitigate project impacts on existing sites. (Mitigation measures are described in the Mitigation of Recreation Facilities section.)

NATIONAL WILDLIFE REFUGE-OPERATED RECREATION SITES

279. Public use of resources on the Upper Souris and J. Clark Salyer National Wildlife Refuges ranges from traditional water-related activities (such as fishing, boating, swimming, and picnicking) to big game hunting.

280. As table 19 shows, Upper Souris National Wildlife Refuge recreation associated with water use comprises 96 to 98 percent of total annual refuge use. Estimated annual visitation has varied over the last 10 years from a high of 121,502 in 1973 to a low of 32,741 in 1978. Spring flooding accounts for some of this fluctuation because it affects early season (May/June) fishing activity, which accounts for 20 to 40 percent of annual refuge use. The locations of recreation sites in the Upper Souris Refuge are shown on exhibit 4.



Recreation Sites in Upper Souris Refuge

EXHIBIT 4

GPO 837-047

Table 19

Upper Souris National Wildlife Refuge

Public Use Visitation, 1972-1982

Year	Recreational Use (1)	Total Public Use
1972	22,324	46,092
1973	120,342	121,502
1974	71,558	73,281
1975	54,647	55,802
1976	37,356	38,140
1977	57,813	59,947
1978	31,540	32,741
1979	48,885	50,590
1980	88,237	89,813
1981	82,762	85,665
1982(2)	50,811	53,152

(1) Recreation activities include picnicking, swimming, boating, and fishing.

(2) Annual use only through September.

Boat Landings 1, 2, and 3

281. The U.S. Fish and Wildlife Service refuge office operates and maintains three boat landings immediately above the Lake Darling Dam. Landing 1, on the west shore of Lake Darling about 150 yards north of the dam, services both lake and shore fishermen. Like other Fish and Wildlife Service landings, this site provides limited picnicking opportunities, parking, and toilet facilities in support of a boat ramp. This site receives an average of about 10 percent of refuge use.

282. Landings 2 and 3 are also on the west shore of the lake, about one-half mile above landing 1. Landing 2 receives about 8 percent of refuge use. Landing 3 is more popular, receiving from 15 to 30 percent of annual refuge use.

Grano Bridge Ramp

283. Located east of the Grano Bridge, this site is used for boat launching and bank fishing. In addition to the ramp, the site includes a comfort station and picnic tables.

Greene Crossing Park

284. Greene Crossing is a 5-acre park west and south of Mohall on State Highway 28 where it crosses Lake Darling. Like the other landings, this site is used for bank fishing and related picnicking in addition to boat launching. Recorded use at this site has increased over the last several years to about 13 to 14 percent of annual refuge use.

Outlet Fishing Area

285. This day-use site consists of a picnic area, two parking areas, a well, and toilet facilities. It is immediately downstream of the Lake Darling spillway. The site will require relocation because of the design of the new spillway.

OTHER RESERVOIR RECREATION SITES

Renville County Recreation Area

286. Renville County Park, located above Darling Dam, is a recreation area and meeting place that has been in use since 1911. Formerly called Mouse River Park, it continues to be a focal point for political, religious, social, and recreational activities within the Upper Souris River basin. The 70-acre park has picnic tables, sanitary facilities, a baseball diamond, campsites, playground equipment, picnic shelters, and four group-use buildings for activities such as roller skating and dancing. Popular recreation activities include swimming, fishing, boating, picnicking, and camping.

287. The proposed levee alternative includes a stop-log structure that would allow recreation craft to pass through and go upstream of the park.

Grano Park (Crossing)

288. Grano Park is on the east shore of Lake Darling. Facilities at this 45-acre site consist of a parking lot, boat ramp, picnic tables, vault toilet, and camping pads. The Renville County Park Board operates and maintains the site, which accounts for approximately 20 to 25 percent of total refuge area recreation use. Previous Corps studies have shown that this site is heavily used by fishermen for access to one of the two areas in Lake Darling open for boat fishing.

289. The mitigation plan for recreation sites (described in the Mitigation of Recreation Facilities section) includes minor modifications to the Grano Park ramp and nearby parking lot. These improvements should more than offset the impacts of the pool raise on the site. Coordination with the North Dakota Parks and

Recreation Department is underway to determine if a conflict related to Section 6 of the Land and Water Conservation (LAWCON) Fund Act (Public Law 88-578) exists. If there is a conflict, a formal resolution process will be initiated.

290. Because construction funds for the park were provided by the LAWCON fund, any mitigation plan must be coordinated through the Secretary of the Interior.

Natural Landmark Program

291. The Upper Souris Refuge has been identified by the U.S. Department of the Interior (in its ecological theme analysis of the Great Plains Natural Region) as having outstanding natural features potentially suitable for a natural landmark designation. These features include stable communities of deciduous lowland forests and native grasses plus seasonal concentrations of native animals, especially waterfowl. Public Law 74-292 requires further coordination with the National Park Service to assess project impacts and possible required mitigation measures associated with the natural landmark program.

DOWNSTREAM RECREATION SITES

Bridge Recreation Sites

292. Two bridge crossings, Baker Bridge and St. Mary's Bridge, are popular sites for bank fishing and picnicking. Baker Bridge is 15 miles north of Minot on Ward County Road 15 where it crosses the Souris River. St. Mary's Bridge, also called Silver Bridge, is 2 miles upstream from Baker Bridge.

Minot Golf Course

293. The Minot Park Board has reported flooding problems at the Souris Valley Golf Course since 1969, and has recorded high costs for restoration of the course during record flood years. Much of the restoration costs have been for removal of silt deposits left after the floods. Bank erosion has also been a problem.

294. A detailed analysis of "with" and "without project" conditions (using historical flood records and information from local golf course officials) has indicated that tradeoffs would occur with the project in place. The dam raise and new operating plan would reduce peak flood levels while slightly increasing durations of river flows at higher than previously recorded levels. The analysis indicates that these tradeoffs are equal in value of benefits and damages at the course and no mitigation is required.

MITIGATION REQUIREMENTS

FISH AND WILDLIFE IMPACTS

295. Fish and wildlife mitigation measures required as a result of adverse impacts of project operation will largely be based on an analysis of changes between the with- and without-project conditions for a range of floods as shown on hydrographs. The area and degree of habitat impacts will be determined using flood profiles on topographic maps. Project effects on water-level management and associated habitat management objectives on the J. Clark Salyer Refuge will also be evaluated.

296. Potential project impacts on aquatic habitat both within and downstream of Lake Darling are currently under study. Of particular concern are effects of construction and reservoir operation on fisheries resources.

297. Determining construction related impacts will require site-specific location and cover typing of all areas to be affected. These areas include borrow sites, excess material disposal sites, work staging areas, site limits of the dam and spillway, roads, and other related facilites. Impacts of required channel modification will also be assessed.

298. A detailed analysis of conditions expected from proposed project operation will be conducted to determine if the project would increase the likelihood of carp migration up the Souris River loop. It cannot be definitely shown at this time that the changes in flows which will result from operation of the Lake Darling project will increase the risk of carp migration into the Souris River in North Dakota. However, the extended higher releases of the recommended operating plan may provide adequate conditions for carp migration farther upstream. Therefore, costs for a carp control structure will be included in the project costs until the analysis is completed. A high-flow/high-velocity channel and a low-flow electric wier at dam 357 are the currently proposed measures for carp control. If carp become established in the Souris loop, effects on waterfowl and fisheries habitats would be severe.

299. Mitigation needs specific to each refuge will be provided for in that refuge. Other mitigation measures will be distributed in each refuge as determined appropriate by the Fish and Wildlife Service. Mitigation will be accomplished by structural and nonstructural measures designed to result in more intensive management of fish and wildlife habitat or the preservation of present management capabilities. No mitigation lands will be acquired.

300. Some of the refuge structures in both the Upper Souris and J. Clark Salyer Refuges will be modified to ensure their continued functioning and management during the revised operating conditions of the Lake Darling Dam. These operating features do not have to be justified by the mitigation analysis. The Refuge Structures section describes the operation features and mitigation features for each refuge. The mitigation features are shown in order of priority as determined by the Fish and Wildlife Service. The extent of structural measures to offset habitat losses resulting from construction and revised operation of the Lake Darling Dam will be determined by the results of the mitigation analysis scheduled for completion in May 1984. Justification for implementation of the number of items on the prioritized list of mitigation features will also be determined at that time.

RECREATION FACILITIES

301. Recreation mitigation measures for the national wildlife refuges have been identified in the Refuge Structures section of this report as operational features because the modification of these facilities is needed for their continued similar operation. The focus in the Upper Souris Refuge is on improvements necessary to ensure that three existing boat ramps remain operable during higher pool elevations and after replacement of the outlet fishing/picnicking area.

302. Existing refuge boat-launching ramps appear to be operable at elevation 1598. This elevation is several feet above the existing Lake Darling conservation pool. With the proposed project, pool elevations should remain close to previous levels except during major floods. Generally, pool elevations would remain several feet higher for only a couple of weeks longer than they have during historic conditions.

303. As coordinated with the Fish and Wildlife Service, the project plan includes modification of three of the most heavily used ramps to keep them operable at elevation 1600. The three ramps are landing 3, Greene Crossing, and Grano Park. Improvements would include earthwork to reshape the existing ramps and to raise parking lots.

304. Replacement of the outlet fishing site would require construction of a new site farther downstream on an existing peninsula across from the pool spillway. Mitigation would include an approximately 3/4-mile extension of the existing access road, a new parking lot, a toilet facility, a canoe-launching crib, and site landscaping. The vault toilet would be designed to be sealed during high water.

305. Recreation mitigation measures in the J. Clark Salyer Refuge would include improvements to existing public boat-launch-

ing sites and exit points on canoe trails.

WOODLAND MITIGATION

306. The results of a detailed analysis of potential direct and indirect (including induced development) adverse project impacts on forest land will be included in the Lake Darling site-specific EIS.

307. An evaluation of aerial photos and topographic delineation of flood discharge outlines downstream of the dam indicates that the level of increased flood protection downstream is generally insufficient to warrant widespread or significant induced development on forest lands. Some small blocks of woodlands in isolated areas may be cleared, but the incentive for clearing will be reduced because of the remaining potential for damages on frequently flooded areas.

308. The Forest Service recommended that losses to native forest lands be mitigated on a 2 to 1 basis. The Corps will quantify adverse impacts to forest lands and consider the recommended level of planting for forest land mitigation during development of the mitigation plan for the Lake Darling site-specific EIS. Planting would be done on project lands and other public lands.

CULTURAL RESOURCES MITIGATION

309. Mitigation of significant cultural resources which would be affected by the proposed work may be required prior to construction. Identification of significant impacts will be conducted during the 1983 field season. The results of this study will be coordinated with the State Historic Preservation Officer and a determination of eligibility requested from the National Register of Historic Places for all significant resources. A mitigation plan will be developed by the St. Paul District and the State Historic Preservation Officer, and it will be presented in a feature design memorandum for cultural resources scheduled for completion in September 1984. Concurrent with this work will be coordination with the Advisory Council on Historic Preservation as outlined in 36 CFR Part 800.

CANADIAN IMPACTS

310. The impacts of altered return flows in Manitoba are considered similar to or less than those evaluated for the Burlington Dam project. A special task force representing both countries has been re-established by the International Joint Commission to examine the Lake Darling project impacts. For this report, a current cost of $774,000 for the mitigation requirements identified in the phase II general design memorandum for the Burlington Dam project is being used.

CORROSION MITIGATION

311. Visual inspection of U.S. Fish and Wildlife dams and structures in the Souris River basin that were constructed in the 1930's does not show any apparent excessive corrosion. Further analysis of past corrosion problems associated with gates and other miscellaneous embedded metals will be made for the feature design memorandums. The feature design memorandum on each structure will provide information to determine the corrosion characteristics of the water at the project and to recommend the type of protection that would be most appropriate from an engineering and economic standpoint.

ACCESS ROADS

312. Existing permanent roads and temporary access roads constructed during the placement of emergency levees will be used for construction of the proposed levees and interior drainage facilities. Permanent access to the eight proposed pumping stations will be provided by constructing short reaches of new road. Access to the Lake Darling Dam and the refuge structures is available on existing permanent roads. Construction on the Soo Line railroad crossing at Greene may require the upgrading of existing seasonal roads.

CONSTRUCTION MATERIALS

GENERAL

313. Construction experience from the Minot channel project indicates that concrete aggregate and ready-mix concrete are available from suppliers in the Minot area. Graded filter material and limited quantities of stone for riprap also are available in Minot. (Graded filter material and bedding material can also be produced from local gravel pits. Pervious fill can be obtained from local gravel pits or from sand and gravel terrace deposits along the valley walls.) Field stone for riprap and/or rock fill can be obtained from the upland areas bordering the Souris River Valley. During construction of the emergency levees in April 1976, considerable quantities of riprap and field stone were placed on the levees and riverbanks. It may be possible to use these materials when building the permanent levees. This possibility will be addressed in site-specific feature DMs.

LAKE DARLING DAM

314. The impervious, random, and berm fill materials will be obtained from required excavation. At present, no borrow is required; however, borrow is readily available from glacial till

deposits on either abutment if needed. Rock fill and riprap must be obtained from field stone piles of glacial boulders in the area. Otherwise, the closest reliable source of quarried stone is Ortonville, Minnesota, a distance of 400 miles. Bedding can be produced from local gravel pits.

LEVEES

315. Materials for the construction of permanent levees is available from glacial till deposits on either of the valley walls. The glacial till is a sandy, silty clay, and it is present in great abundance in the project area.

RESERVOIR CLEARING

316. All areas to be occupied by permanent structures, borrow pits, and stockpile and wastepile sites will be cleared of all trees, stumps, roots, brush, and other objectionable matter. The duration of reservoir storage above elevation 1600 is not expected to affect the woodlands in the reservoir. There are some woodlands below elevation 1600 which may lose some trees. However, debris accumulation is not expected to generate a problem in the operation of Lake Darling Dam. Therefore, none of the reservoir woodlands will be cleared, except as noted above.

ENVIRONMENTAL QUALITY ENHANCEMENT MEASURES

317. Environmental quality (EQ) is the quality of resources in the human environment that are natural or cultural forms, processes, systems, or other phenomena that: (1) are related to land, water, atmosphere, plants, animals, or historic or cultural objects, sites, buildings, structures, or districts; and (2) have one or more EQ attributes or properties (ecological, cultural, or aesthetic).

318. Enhancement of the environment is a consideration in the planning and implementation of water resource development projects. Environmental quality measures may be incorporated into a recommended plan as long as the primary purposes authorized by Congress are accomplished. Measures proposed for EQ must enhance, preserve, or restore the environment and must be related to, or take advantage of, opportunities created by a water resource development to be recommended for implementation.

319. EQ features proposed are not for mitigation of adverse impacts attributable to the project. Mitigation measures are proposed through (1) planning and designing features to avoid or lessen adverse impacts; and (2) the use of other structural or nonstructural measures. Mitigation measures maintain environmental values at a level no more than the "without-project"

condition. EQ measures are taken to preserve, enhance, or restore environmental values at a level greater than the "without-project" condition.

320. Separable EQ measures which could be implemented as part of the Lake Darling flood control project have been identified. They would meet at least one of the criteria for recommendation without advance approval of the Director of Civil Works as outlined in ER 1165-2-28, Corps of Engineers Participation in Environmental Quality.

ECKERT RANCH

321. It is planned to protect Eckert Ranch from Lake Darling storage by a levee and by diversion of a tributary drainage area. Runoff from the ranch's livestock pens currently enters Lake Darling and causes a water quality problem because of the nutrients and biochemical oxygen demand contained in this effluent. An impoundment to contain this runoff could be incorporated into the project feature. The impoundment could eliminate or reduce the severity of this point-source water quality problem. The measure would help restore the value of the EQ resources of water quality and aquatic habitat to a level greater than the without-project condition. The measure is related to, and takes advantage of, an opportunity created by the flood control project feature and satisfies the criteria for recommendation without advance approval in that it is more cost effective to implement when directly integrated with the implementation of the project feature.

RENVILLE COUNTY PARK

322. It is proposed to protect Renville County Park by a channel cutoff and a levee with tiebacks into high ground upstream and downstream of the park area. Renville County Park has been identified as an EQ resource with cultural and aesthetic attributes. The park would likely experience river flooding damages during the future-without-project condition. Although flood control measures are required for the park because of the raised flood pool elevation from the Lake Darling Dam raise, these measures would also protect the park from initial river floods. These measures would preserve the quality of the park's attributes at a level greater than the without-project condition. Considering the two different flood situations, the flood control features meet the criteria for both mitigation and environmental quality. Therefore, the EQ measure is strongly tied to implementation of the proposed feature.

MCKINNEY CEMETERY

323. The plan for protection of McKinney Cemetery consists of a levee and a flap-gated outlet. McKinney Cemetery is an important EQ resource (the site is listed on the National Register of Historic Places) with cultural and aesthetic attributes. As with Renville County Park, McKinney Cemetery would likely experience river flooding damage during the future without-project condition.

324. The levee is required in lieu of relocation to protect the cemetery from flooding from the raised flood pool after the Lake Darling Dam raise. It would also protect it from initial river flood crests before the flood pool fills enough to affect the cemetery. The levee would preserve the environmental quality of the cemetery at a level greater than the without-project condition. Again, as with the Renville County Park situation, the levee protects the cemetery from two different flood situations and meets both mitigation and environmental quality criteria.

REAL ESTATE REQUIREMENTS

RESERVOIR LANDS

325. All lands in the reservoir area are to be acquired at complete Federal expense. The plan will require that perpetual flowage easements be acquired over approximately 1,180 acres of privately owned land upstream from Lake Darling Dam. This is based on a design pool elevation of 1605 and a guide taking contour of elevation 1607. An estimated 25 ownerships are affected. Included within these 1,180 acres are approximately 80 acres from about 20 ownerships needed to eliminate existing and future break out points. Most of the lands to be acquired are agricultural, suitable for crops and cattle grazing. No structures are to be acquired for the reservoir area or break out points.

326. Flood protection measures at Renville County Park will require approximately 25 acres of land for construction of a cutoff channel, levee, and pump station. Most of the land upon which these structures are to be located is owned by the U.S. Fish and Wildlife Service. Perpetual easements for the levee and channel will be acquired from approximately four private land owners. No structures are to be acquired.

327. Flood protection measures at McKinney Cemetery consist of a levee and drainage ditch, requiring about 8 acres of land. Because all of this land is located on U.S. Fish and Wildlife property, it will not be necessary to acquire a real estate interest in any private property. No structures or improvements will be affected by this plan.

328. Flood protection at the Eckert Ranch consists of a levee and drainage ditch, requiring approximately 5 acres of land. Perpetual easements for the levee and ditch will be acquired from one private landowner. No structures will be acquired.

URBAN LEVEES

329. The local sponsor for the project will be responsible for acquiring all rights-of-way for urban levees. Protection of the eight subdivisions between Burlington and Minot will require construction of six separate levees and associated ponding areas and access roads. Perpetual easements for the levee, ponding, and access areas will be acquired from an estimated 111 private landowners. Approximately 40 acres of land will be acquired, including 8 residences. Public Law 91-646 relocation benefits will be provided to all qualified owners and tenants displaced by the project. A breakdown of acreages, ownerships, and residential structures to be acquired for each protected area is shown in the following table.

Table 19a

Real Estate at Urban Levee Areas

Protected Areas	Est. Ownerships Affected	Residences Affected	Levee Acreage	Access & Ponding Area Acreage
Johnson's Addition	13	2	6.20	.09
Brook's Addition	17	1	6.59	
Talbott's Nursery	8	5	3.65	
Country Club Acres & Robinwood Estates	25	0	9.89	.07
King's Court & Rostad's Addition	25	0	5.55	
Tierrecito Vallejo	23	0	7.05	.80
Totals	111	8	38.93	.96

330. Flood protection at the community of Sawyer requires the acquisition of perpetual easements over approximately 6 acres needed for levee construction. An estimated 17 ownerships will be affected. No structures are to be acquired.

331. The project at Velva will require the local sponsor to acquire perpetual easements over approximately 50 acres of land. Forty-one acres are required for levees and channel improvement work, and the balance are needed for ponding areas. These easements will be acquired from approximately 37 ownerships. Present land uses in the project area are agricultural, city park, wooded river bottom, and residential. One single-family residence will be acquired.

DOWNSTREAM RURAL MEASURES

332. Approximately 570 acres downstream of Lake Darling Dam would be adversely affected by the proposed 5,000 cfs releases from the dam. Included within these 570 acres are 12 residences. Perpetual flowage easements would be acquired over these lands, and the 12 residences would also be acquired. Occupants of any acquired residence would be eligible for relocation benefits under Public Law 91-646. All costs of acquiring these lands and residences will be at complete non-Federal expense.

COST ESTIMATES

333. This estimate of costs is based on October 1983 price levels and reflects recent prices for similar work in the St. Paul District. The unit prices used in the estimates are based on the assumption that each major project feature will be constructed by separate contractors, possibly at different times. Table 20 presents a comparison between the current estimate (PB-3 dated April 1983) and the revised estimate prepared for this design memorandum. A detailed estimate of costs is shown in appendix D.

Table 20

Summary of Estimated First Costs
(October 1983 Price Levels)

Lake Darling Dam Unit

Federal Costs		Current Estimate from PB3 Dated April, 1983	Revised Estimate this Design Memo
01	Lands and Damages - Reservoir	1,860,000	314,000
	Payments	(1,515,000)	(234,500)
	Acquisition Costs	(335,000)	(77,500)
	Land Management	(10,000)	(2,000)
02	Relocations	7,060,000	11,857,000
02.1	Roads	(3,734,000)	(6,221,000)
	State Highway 5	256,000	1,331,000
	State Highway 28	427,000	1,791,000
	Grano Crossing	2,837,000	2,005,000
	Renville Co. Road 9	214,000	94,000
	Lake Darling Dam Crossing	0	1,000,000
02.2	Soo Line Railroad	(3,210,000)	(5,485,000)
02.3	Cemeteries, Utilities & Structures	(116,000)	(151,000)
	Power Lines		69,000
	Telephone Lines		57,000
	Water Supply System		25,000
03	Reservoir	58,000	

Table 20 (Cont)

Federal Costs		Current Estimate from PB3 Dated April, 1983	Revised Estimate this Design Memo
06	Fish and Wildlife Facilities	32,620,000	28,541,400
06.1	Lake Darling Dam	(27,187,000)	(17,100,000)
06.2	Upper Souris Refuge Operation Features	(2,000,000)	(2,660,000)
06.3	Upper Souris Refuge Mitigation Features	(1,073,000)	(2,147,400)
06.4	J. Clark Salyer Refuge Operation Features	(1,608,000)	(1,701,000)
06.5	J. Clark Salyer Refuge Mitigation Features	(752,000)	(5,433,000)
09	Channels	774,000	924,000
	Canadian Compensation	(774,000)	(774,000)
	Hydrometeorological Instrumentation	(0)	(150,000)
09	Levees	0	1,372,000
	Renville County Park	(0)	(1,060,000)
	McKinney Cemetery	(0)	(112,000)
	Eckert Ranch	(0)	(200,000)
19	Buildings, Grounds, and Utilities	12,000	12,000
20	Local Protection from Gassman Coulee	250,000	250,000
30	Engineering and Design	3,350,000	3,350,000
31	Supervision and Administration	2,716,000	2,879,600
	Supervision and Inspection	(1,836,000)	(1,951,600)
	Overhead	(880,000)	(928,000)
	Total - Lake Darling Dam Unit (Federal Funds Only)	48,700,000	50,000,000

Table 20 (Cont)

Burlington to Minot Levees Unit

Federal Costs		Current Estimate from PB3 Dated April, 1983	Revised Estimate this Design Memo
09	Channels	1,008,000	380,000
11	Levees	3,410,000	1,921,000
	Embankments	(2,486,000)	(1,209,000)
	Interior Drainage Facilities	(924,000)	(712,000)
13	Pumping Plants	1,386,000	961,000
30	Engineering and Design	501,000	407,000
31	Supervision and Administration	395,000	214,000
	Supervision and Inspection	(266,000)	(151,500)
	Overhead	(129,000)	(62,500)
	Total Federal Costs	6,700,000	3,883,000
Non-Federal Costs			
	Lands and Damages	973,000	1,260,000
	Payments		(1,010,000)
	Acquisition Costs		(250,000)
	Relocations	107,000	64,000
	Total Non-Federal Costs	1,080,000	1,324,000
Total Federal & Non-Federal Costs - Burlington to Minot Levee Unit		7,780,000	5,207,000

Table 20 (Cont)

Sawyer Levees Unit

Federal Costs		Current Estimate from PB3 Dated April, 1983	Revised Estimate this Design Memo
11	Levees	394,000	302,000
	Embankments	(322,000)	(237,000)
	Interior Drainage Facilities	(72,000)	(65,000)
30	Engineering and Design	42,000	36,000
31	Supervision & Administration	24,000	20,000
	Supervision and Inspection	(16,000)	(14,000)
	Overhead	(8,000)	(6,000)
	Total Federal Costs -	460,000	358,000
Non-Federal Costs			
	Lands and Damages	91,000	130,000
	Payments		(90,000)
	Acquisition Cost		(40,000)
	Relocations	18,000	11,000
	Total Non-Federal Costs	109,000	141,000
Total Federal and Non-Federal Costs - Sawyer Levees Unit		569,000	499,000

Table 20 (Cont)

Velva Levees Unit

Federal Costs		Current Estimate from PB3 Dated April, 1983	Revised Estimate this Design Memo
09	Channels	2,567,000	2,567,000
11	Levees	1,335,000	1,335,000
	Embankments	(341,000)	(341,000)
	Interior Drainage Facilities	(994,000)	(994,000)
13	Pumping Plants	207,000	207,000
30	Engineering and Design	420,000	420,000
31	Supervision & Administration	301,000	301,000
	Supervision & Inspection	(185,000)	(185,000)
	Overhead	(116,000)	(116,000)
	Total Federal Costs	4,830,000	4,830,000
Non-Federal Costs			
	Lands and Damages	269,000	269,000
	Payments	(221,000)	(221,000)
	Acquisition Cost	(48,000)	(48,000)
	Relocations	67,000	67,000
	Total Non-Federal Costs	336,000	336,000
Total Federal and Non-Federal Costs - Velva Levees Unit		5,166,000	5,166,000

Table 20 (Cont)

Rural Improvements Unit

Federal Costs		Current Estimate from PB3 Dated April, 1983	Revised Estimate this Design Memo
02	Relocations	3,877,000	4,320,000
30	Engineering and Design	545,000	300,000
31	*Supervision & Administration*	288,000	288,000
	Supervision & Inspection	(205,000)	(194,000)
	Overhead	(83,000)	(94,000)
	Total Federal Costs	4,710,000	4,908,000
Non-Federal Costs			
	Lands and Damages	390,000	2,352,000
	Payments		(2,250,000)
	Acquisition Costs		(102,000)
	Relocations	790,000	0
	Total Non-Federal Costs	1,180,000	2,352,000
	Total Federal and Non-Federal Costs - Rural Improvements Unit	5,890,000	7,260,000
Total Federal Costs - Lake Darling Project		65,400,000	63,979,000
Total Non-Federal Costs - Lake Darling Project		2,705,000	4,153,000
Total Federal & Non-Federal Costs - Lake Darling Project		68,105,000	68,132,000

334. The difference between this design memorandum cost estimate ($68,132,000) and the latest PB3 estimate of April 1983 ($68,105,000) is attributable to the following:

Lake Darling Dam Unit

a. Lands and damages

(1) Decrease in cost resulting from reduction in estimated real estate needs.	-$286,000
(2) Decrease in cost at Renville County Park and Eckert Ranch because these costs have been reclassified as levee features.	-$1,260,000

b. Relocations

(1) Increase in cost of modifying State Highway 5 because of more extensive modifications than previously estimated.	+$1,075,000
(2) Increase in cost of modifying State Highway 28 because of more extensive modifications than previously estimated.	+$1,364,000
(3) Decrease in cost of modifying Grano crossing because of adjustment in unit prices.	-$832,000
(4) Decrease in cost of modifying Renville Co. Road 9 resulting from reduction in quantities estimated for stabilization.	-$120,000
(5) Increase in cost resulting from separation of costs for Lake Darling Dam bridge and approaches (was previously included in cost of raising Lake Darling Dam).	+$1,000,000
(6) Increase in cost of modifying Soo Line Railroad because of adjustment in unit prices and more extensive modifications than previously estimated.	+$2,275,000
(7) Increase in cost because of more extensive utility relocation costs than previously estimated.	+$147,000

(8) Decrease in cost of McKinney Cemetery because this cost has been reclassified as a levee feature. -$112,000

c. Reservoir - Decrease in cost because there is no work identified for this classification. -$58,000

d. Lake Darling Dam

(1) Decrease in cost resulting from revised design to raise maximum reservoir pool from elevation 1605 to elevation 1609. -$3,780,000

(2) Decreased cost resulting from placing low-flow outlets in the spillway piers in lieu of a separate outlet structure. -$3,000,000

(3) Decrease in cost of bridge and approaches because of transfer to relocations costs. -$1,000,000

(4) Decrease in cost because of adjustment in unit prices. -$2,307,000

e. Other Fish and Wildlife Measures

(1) Increase in cost for Upper Souris Refuge operation features (which were previously subcatagorized asdam 41, dam 87, dam 96, and miscellaneous work within the category of "other refuge structures") because of adjustment in unit costs and more extensive modifications than previously estimated. +$660,000

(2) Increase in cost of Upper Souris Refuge mitigation features (which were previously identified as general "mitigation measures") because of more extensive modifications then previously estimated. A list of possible mitigation features is provided; however, all the listed features may not be recommended by the upcoming mitigation study. +$1,074,400

(3) Increase in cost of J. Clark Salyer Refuge operation features (which previously were subcategorized

as carp control facilities and miscellaneous work within the category of "other refuge structures") because of adjustment in unit costs. +$93,000

(4) Increase in cost of J. Clark Salyer Refuge mitigation features (which were previously included in "other refuge structures") because of more extensive modifications than previously estimated. A list of possible mitigation features is provided; however, all the listed features may not be recommended by the upcoming mitigation study. +$4,681,000

f. Channels - Increase in cost resulting from addition of hydrometeorological instrumentation feature which is considered necessary for proper operation of the project. +$150,000

g. Levees - Increase in cost resulting from reclassification of Renville County Park from Lands and Damages, McKinney Cemetery from Relocations, and Eckert Ranch from Lands and Damages. +$1,372,000

h. Supervision and Administration - Increase in cost due to revised rates of S & I and overhead applied to construction work. +$163,600

Burlington to Minot Levees Unit

a. Channels - Decrease in cost resulting from adjustment in unit costs and previous estimate was based on a higher degree of protection. -$628,000

b. Levees - Decrease in cost because of adjustment in unit costs and because previous estimate was based on a higher degree of protection. -$1,489,000

c. Pumping Plants - Decrease in cost because of adjustment in unit costs and because previous estimate was based on a higher degree of protection. -$425,000

d. Engineering and Design - Decrease in cost resulting from a reduced construction cost. -$94,000

e. Supervision and Administration - Decrease in cost resulting from a reduced construction cost. -$181,000

f. Lands and Damages - Increase in cost resulting from a re-evaluation of real estate needs and a reclassification of some relocations costs. +$287,000

g. Relocations - Decrease resulting from transfer of costs for relocation of structures to Lands and Damages. -$43,000

Sawyer Levees Unit

a. Levees - Decrease in cost because of adjustment in unit costs and because previous estimate was based on a higher degree of protection. -$92,000

b. Engineering and Design - Decrease in cost resulting from a reduced construction cost. -$6,000

c. Supervision and Administration - Decrease in cost resulting from a reduced construction cost. -$4,000

d. Lands and Damages - Increase in cost resulting from a re-evaluation of real estate needs and a reclassification of some relocations costs. +$39,000

e. Relocations - Decrease in cost resulting from transfer of costs for relocation of structures to Lands and Damages. -$7,000

Velva Levees Unit

No change.

Rural Improvements Unit

a. Cost of relocations at Federal expense increased because of a transfer from the non-Federal relocation costs and adjustments in unit costs. Re-evaluation of structural measures is viewed to include no non-Federal relocation costs. +$443,000

b. Engineering and Design - Decrease in cost to provide for a consistent percentage of construction costs for all project features. -$245,000

c. Lands and Damages - Increase in cost because of identified need to acquire residences that are to be relocated and increase in required flowage easements. +$1,962,000

d. Relocations at non-Federal cost - Decrease resulting from transfer to Federal costs or Lands and Damages. -$790,000

TOTAL CHANGE (October 1983 price level) +$27,000

SCHEDULE FOR DESIGN AND CONSTRUCTION

335. The current schedule for design and construction, presented in table 21, is subject to availability of funds. The schedule is based on initial appropriation of construction funds in fiscal year 1985. The initial construction work scheduled for November 1984 would include channel improvements at the Highway 41 bridge in Velva, North Dakota, as part of the Velva Levee improvement unit. The project will be constructed by contract over a period of about 4 years.

Table 20a

Current Design and Construction Schedule

Item	Submit Initial Design Memo	Initiate Construction	Complete
Velva Improvements	Nov 82	Nov 84	Nov 86
Highway Relocation	Aug 84	July 85	Sep 87
Burlington to Minot Improvements	Oct 84	Apr 86	Sep 88
Utility Relocations	Nov 84	July 85	Sep 88
Reservoir Levees	Jan 85	May 86	Sep 88
Railroad Relocations	Apr 85	Oct 86	July 89
Lake Darling Dam	June 85	Mar 86	July 89
Sawyer Improvements	Nov 85	Apr 87	Sep 88
Refuge Structures	Nov 85	Apr 87	July 89
Gassman Coulee	Jan 86	Apr 88	Sep 88
Rural Downstream Improvements	Feb 86	May 87	Aug 89

OPERATION AND MAINTENANCE

336. Table 21 provides the estimated operation and maintenance costs of this flood control project and indicates which agency or group is viewed to be responsible for the operation and maintenance of each feature.

Table 21

Operation and Maintenance Responsibilities
By Project Feature

Feature	Estimated Increase in O&M Costs	Responsibility
Lake Darling Dam	$190,000	Federal - COE
Other refuge structures (Upper Souris & J. Clark Salyer)	$ 8,000	Federal - FWS
Reservoir roads, railroads, bridges, utilities	- 0 -	Non-Federal owner
Reservoir levees	$ 4,300	Local sponsor
Downstream features (including urban & rural levees, access roads, Gassman Coulee protection)	$ 43,700	Local sponsor

LAKE DARLING DAM

337. The operation and maintenance of the Lake Darling Dam will continue to be a Federal responsibility. The structure is owned, operated, and maintained by the U.S. Fish and Wildlife Service. However, the structure is being upgraded for flood control purposes with Corps of Engineers funding and using Corps design criteria. Therefore, in addition to FWS standards for operation and maintenance of the dam, the Corps must be assured that the structure is maintained to its standards. It is evident that the annual operation and maintenance costs will be higher for post-project conditions. Besides any additional inspections or maintenance required for Corps standards, the gated spillway and more sophisticated flood forecasting methods will result in higher annual costs. It is viewed that funding for these additional annual costs should be the responsibility of the Corps of Engineers. The operation and maintenance costs shown in table 22 represent the total amount needed annually for Lake Darling Dam.

338. Issues such as (1) whether the U.S. Fish and Wildlife should share in these annual costs; (2) should the Corps maintain the structure or provide funds for the Fish and Wildlife Service to maintain it; and (3) the mechanics of appropriating annual operation and maintenance funds will be addressed in the Section 7 agreement between the two

agencies. This agreement is required by the 1944 Flood Control Act and will address all responsibilities and procedures for the construction, operation, and maintenance of the Lake Darling Dam. The memorandum of understanding, which would be the formal agreement of compliance with Section 7 requirements, may be in two phases. The first phase, concerning right-of-way, would be required prior to a construction start at the dam. The second phase, addressing operation, would be required before construction is completed at the dam.

Table 22

Lake Darling Dam
Estimated Operation and Maintenance Costs

Item	Annual Cost
Operation	
Dam Operations	$ 13,000
Reservoir Operations	20,000
Buildings, Grounds, and Utilities	6,000
Equipment	6,000
National Resource Studies	6,000
Periodic Inspection	24,000
Dam Instrumentation	12,000
Pool Regulation	2,000
Discharge Observation and Gages	20,000
Supervision and Inspection	6,000
Supervision and Administration	30,000
Total Operations	$145,000

Maintenance and Replacement	Annual Cost
Dam Maintenance	$ 16,000
Permanent Operating Equipment	9,000
Building, Grounds, and Utilities	6,000
Miscellaneous Engineering & Design	5,000
Supervision and Administration	10,000
Total Maintenance & Replacement	$ 46,000
Total Operation & Ma.ntenance	$190,000

UPPER SOURIS AND J. CLARK SALYER REFUGE STRUCTURES

339. There will be additional costs associated with utilities needed for operation of the gate actuators and heaters. However, these costs will be more than offset by the savings related to reduced manual labor. Current conditions require the placement of baled straw adjacent to the gates to prevent ice damage and to make it easier to remove the ice in the spring. Also, many hours are required to manually chip the ice away from the gates in the spring. With heaters, the effort required to begin gate operation each spring will be significantly reduced. The heaters would not operate throughout the winter, but rather for a period of several weeks in late winter or spring when the gates are to be adjusted.

340. The carp control structure is included in the project plan at this time until further studies determine whether the revised operation of Lake Darling Dam will provide a better opportunity for rough fish to migrate upstream to the United States portion of the Souris River. The means of preventing access to carp at low flows, an electric weir used when flows would be less than approximately 700 cfs, would require constant electrical service. The electric weir would be operated approximately 10 months a year for an estimated annual cost of $8,000. This cost would be borne by the U.S. Fish and Wildlife Service.

RESERVOIR LEVEES

341. Local interests will be responsible for the operation of the pumping station at Renville County Park and for providing pumping as necessary by means of temporary pumps at other levee areas. Gate closures, placement of stop logs in closure structures, and servicing and maintenance of equipment, structures, and related landscaping, as necessary, are also the responsibility of local interests. Operating instructions will be provided to the appropriate local officials for completed portions of the project as they become operable.

342. Because the operation of Lake Darling Dam directly affects the water stages at the reservoir levee areas, a close line of communication will be required between the dam operator and the designated individual representing the local interests on projected lake levels.

343. The acquisition of any required real estate in the reservoir area is recommended to be in the form of flowage easements. A one-time payment at the time of project construction to cover the estimated decrease in property value resulting from future changed conditions is the only cost associated with the easement. Therefore, no additional annual costs for the reservoir real estate have been assessed.

344. The estimated annual costs for operating and maintaining the recommended levee areas in the reservoir area are shown on table 23.

Table 23

Reservoir Levees
Annual Operation and Maintenance Costs

	Renville County Park	Eckert Ranch	McKinney Cemetery
Levee Length	5,500'	1,000'	1,000'
Levee Height	9'	9'	9'
Interior Pumping	1 Pumping Station (gal./min.)	Portable Pump	Portable Pump
Gate Closure Elev.	1598	(Flap Gate)	(Flap Gate)
Frequency of Gate Closure			
Annual Operation Costs (pumping, gate operation, levee surveillance)	$ 550	$ 100	$ 50
Annual Maintenance Costs (levee mowing & weed control, erosion repair, machinery upkeep & lubrication)	3,000	150	200
Replacement Costs (pumps, gates, machinery)	150	50	50
Total Annual O&M Costs	$3,700	$ 300	$ 300

RESERVOIR CROSSINGS

345. The highway and railroad crossings in the reservoir area will be subjected to higher stages and storage for longer durations. These conditions would increase the operation and maintenance costs if no improvements were made to the crossings. However, in addition to the proposed raising of the bridges and their approaches, costs have been included to provide riprap protection adequate to withstand wave and velocity conditions made worse by the raised Lake Darling Dam. Therefore, the operation and maintenance costs would not increase with the project, but may even decrease because of the replacement of these facilities with new structures.

DOWNSTREAM URBAN LEVEES & RURAL FLOODPROOFING

346. Local interests will be responsible for the operation of the pumping station and all related gate closures on sewers, the installation and removal of sand bags for closure structures, and the servicing and maintenance of equipment, structures, and related landscaping as necessary. Operating instructions will be provided to the appropriate local officials for completed portions of the project as these become operable. This will ensure proper operation of the partially completed project during the extended period required for construction of the total project. Annual operation and maintenance costs are shown on tables 24 & 25.

LOCAL PROTECTION FROM GASSMAN COULEE

347. Operation of the system includes seasonal preparation of precipitation gages; lubrication, cleaning, and adjustment of instruments; cleaning and periodic replacement of batteries; charging of propane storage tanks for thermal generators; changing of paper punch tape at the streamflow recorder; and record maintenance. The staff required to operate the flood-warning system is based upon part-time participation of full-time employees. Field maintenance of remote stations may be performed incidental to other tasks. The estimated annual costs of operating and maintaining the system are shown on table 26.

Table 24

Downstream Urban Levees –
Annual Operation and Maintenance Costs

	Burlington to Minot	Sawyer	Velva
Levee Length	28,300'	4,200'	10,200'
Average Levee Height	5'	5'	8'
Number of Gatewells	7	1	6
Number of Levee Closures			2
Number of Pump Stations	6	0	1
Frequency of Gate Closure	2/yr.	2/yr.	2/yr.
Frequency of Design Exceedence	27/yr.	22/yr.	100/yr.
Annual Operation Costs (pumping, gate operation, levee surveillance, closure structures)	$2,770	$410	$1,000
Annual Maintenance Costs (levee mowing & weed control, erosion repair, machinery upkeep & lubrication)	$15,800	$2,265	$5,700
Rep..cement Costs (pumps, gates, machinery, stop logs)	$830	$125	$300
Total Annual O&M Costs	$19,400	$2,800	$7,000

Table 25

Rural Floodproofing Measures -
Annual Operation and Maintenance Costs

No. of Areas Protected with Levees	50
Average Levee Height	4.5'
Average Levee Length	250
Frequency of Gate Closure	(Flap Gates - 2/yr.)
No. of Sanitary Holding Tanks	73
<u>Annual Operating Costs</u>	
Temporary Pumping	$3,000
Levee Surveillance	500
Sanitary Holding Tanks	1,000
<u>Annual Maintenance Costs</u>	
Levee Maintenance	1,000
Gate Lubrication and Upkeep	500
Access Road Maintenance	1,000
<u>Replacement Costs</u>	
Portable Pumps	1,500
Total	$8,500

Table 26

Local Protection from Gassman Coulee
Annual Operating and Maintenance Costs

Remote site maintenance		$ 1,200.00
Check instruments		
Adjust and lubricate bearings		
Exchange batteries		
Exchange malfunctioning components		
Paper tape for punch recorder		20.00
Propane (22.4 lbs/wk)		700.00
File data		380.00
Component repair		800.00
Periodic discharge observation		2,000.00
Spare parts		400.00
Contingency		500.00
	Total	$ 6,000.00

FLOOD FORECASTING

348. The limited flood control storage available in Lake Darling makes it necessary to have timely and accurate inflow information. The computer models which were run assumed 72 hours of foresight on inflows. A reduction in this amount of time would significantly reduce the flood control performance of the dam. For this reason, the additional real-time gages in Canada are an essential part of the Lake Darling Flood Control Plan.

349. The collection and distribution of hydrologic data in the Souris River basin is a complex task involving at least 13 government agencies in the United States and Canada. Data collection is outlined below as applicable to the United States portion of the Souris basin. For further information, see the "Souris River Basin Streamflow Forecasting and Inter-jurisdictional Liaison Handbook" by the Souris River Flow Forecasting Liaison Committee, Souris River Board of Control.

350. Saskatchewan: Water Survey of Canada operates the stream gaging network in Saskatchewan, collecting data from 27 gages on the Souris River and tributaries. Atmospheric Environment Service of Environment Canada operates the meteorological surveys for Saskatchewan, collecting data from 15 stations. Saskatchewan Department of the Environment operates the snow surveys, collecting data from 20 snow courses in early February, early and mid-March, and early April. Data collected by these agencies are reported to interested agencies in the United States and Manitoba, generally by telephone and with confirmation by mail.

351. United States: The National Weather Service (NWS) and its offices collect the basic meterological data used in forecasts from 32 stations in North Dakota. The U.S. Geological Survey operates gages at 22 stations, including six on the main stem of the Souris. The U.S. Fish and Wildlife Service supplies data on levels at Lake Darling Dam. Snow surveys are done by the NWS and the Corps of Engineers. The NWS also does snow surveys by aerial gamma-radiation survey, usually coinciding with surface data collections for calibration purposes.

352. The only U.S. gage on the Souris upstream of Lake Darling is located at Sherwood. Records and reliability are good, but travel time from the gage to the reservoir is relatively short (about 2 days during high flows). Lack of adequately accurate and reliable data upstream of Sherwood is a limiting factor in the present operation of Lake Darling during flood periods. After the raise of Lake Darling, this information will be even more critical to proper flood control operation.

353. In order to provide information to the U.S. agencies in time for proper forecasting for Lake Darling, several Canadian gages will have to be converted to real-time reporting into the GOES satellite system of the National Oceanographic and Atmospheric Administration (NOAA), from the data collection platforms (DCP) at the gage sites. The sites required to be converted are Moose Mountain Creek at Oxbow, Souris River at Glen Ewen, and Souris River at Roche-Percee.

354. Local gage readers should be hired to obtain check data weekly, and to provide readings by telephone in case of equipment failure. Two other DCP gages are needed at Moose Mountain Creek at #9 highway, south of Carlyle, and at Souris River, either downstream of Dead Lake (first choice) or near Halbrite (second choice).

355. These five gages would provide enough additional data for the NWS River Forecast Center, the FWS, and the Corps to make timely forecasts of inflow volumes at Lake Darling.

356. Sufficiently early information is required to start pre-flood drawdown of Lake Darling by 1 March because of downstream constraints on winter flow changes and relatively low release rates required. Because snow surveys take several days and aerial gamma surveys take about a week to analyze by computer, sufficient lead time must be allowed in planning drawdown. The present early February-early March sequence leaves a significant gap where information is most needed. An additional snow survey is needed in February to provide input for 1 March. It is therefore suggested that the "early March" survey be moved up to late February. As the later survey results are posted in mid-March, the progress of drawdown can be reanalyzed and modified as necessary to compensate for changes in the snowpack.

PRE-FLOOD DRAWDOWN

357. The first phase of flood control operation is called the drawdown phase. From early January on, planning is based on the accumulated precipitation plus long range outlooks for snowfall. In February and March, snow surveys provide additional data on snow water content. By 1 March, the pool is at or below elevation 1596. Flood volume forecasts based on accumulated plus anticipated precipitation provide input to determine the target drawdown elevation. Exhibit 5 shows the target elevation curve based on 30-day flood volume forecasts. Flows from Lake Darling are adjusted to achieve the required level by late March.

PEAK DISCHARGE

358. The second phase lasts from the start of snowmelt until peak reservoir stage is reached. Exhibit 6 shows the peak target discharge at

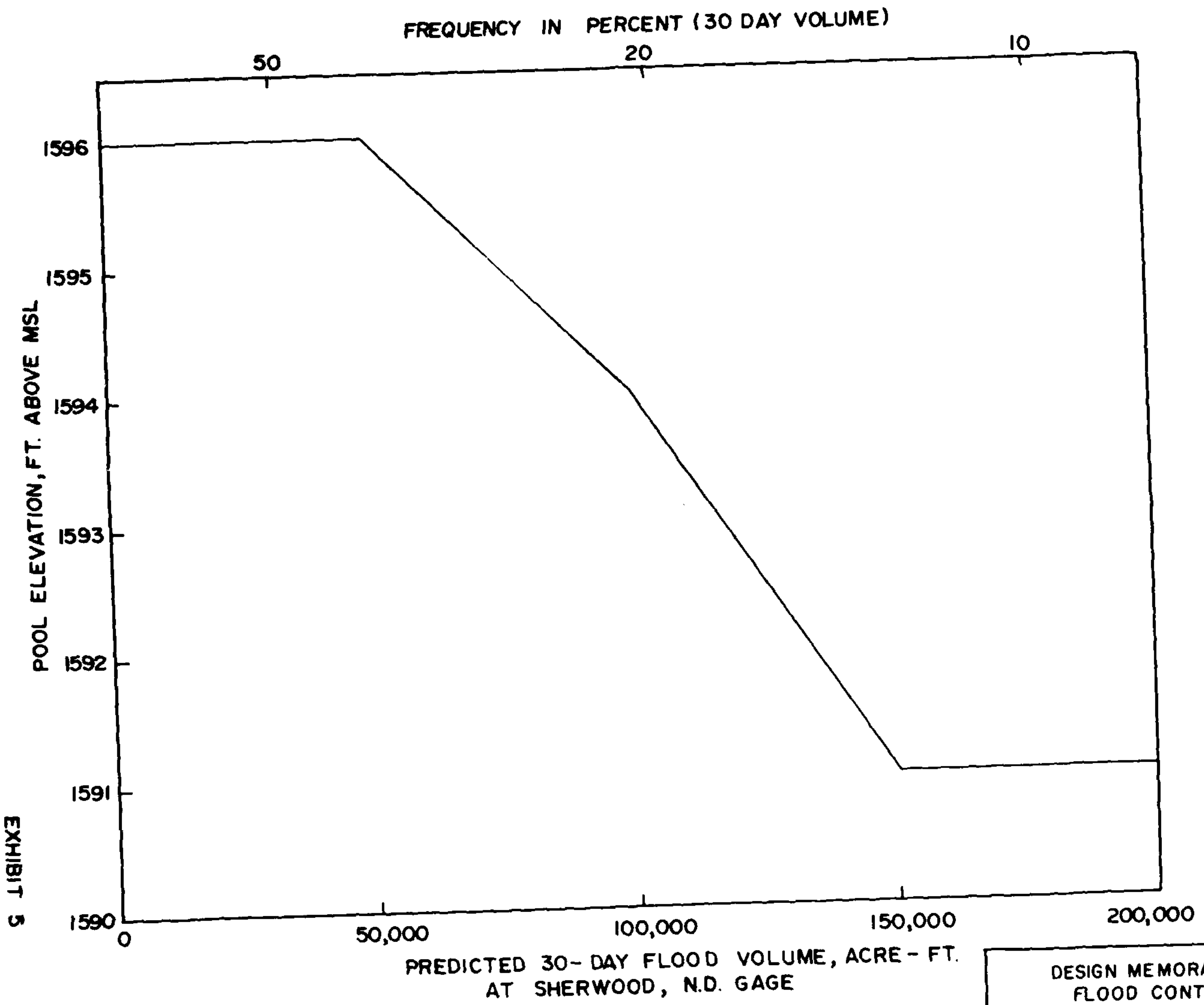


EXHIBIT 5

DESIGN MEMORANDUM NO 3 GENERAL
FLOOD CONTROL LAKE DARLING
SOURIS RIVER NORTH DAKOTA
LAKE DARLING - FLOOD CONTROL OPERATION
RESERVOIR TARGET DRAWDOWN LEVELS
ST. PAUL DISTRICT JUNE 1983

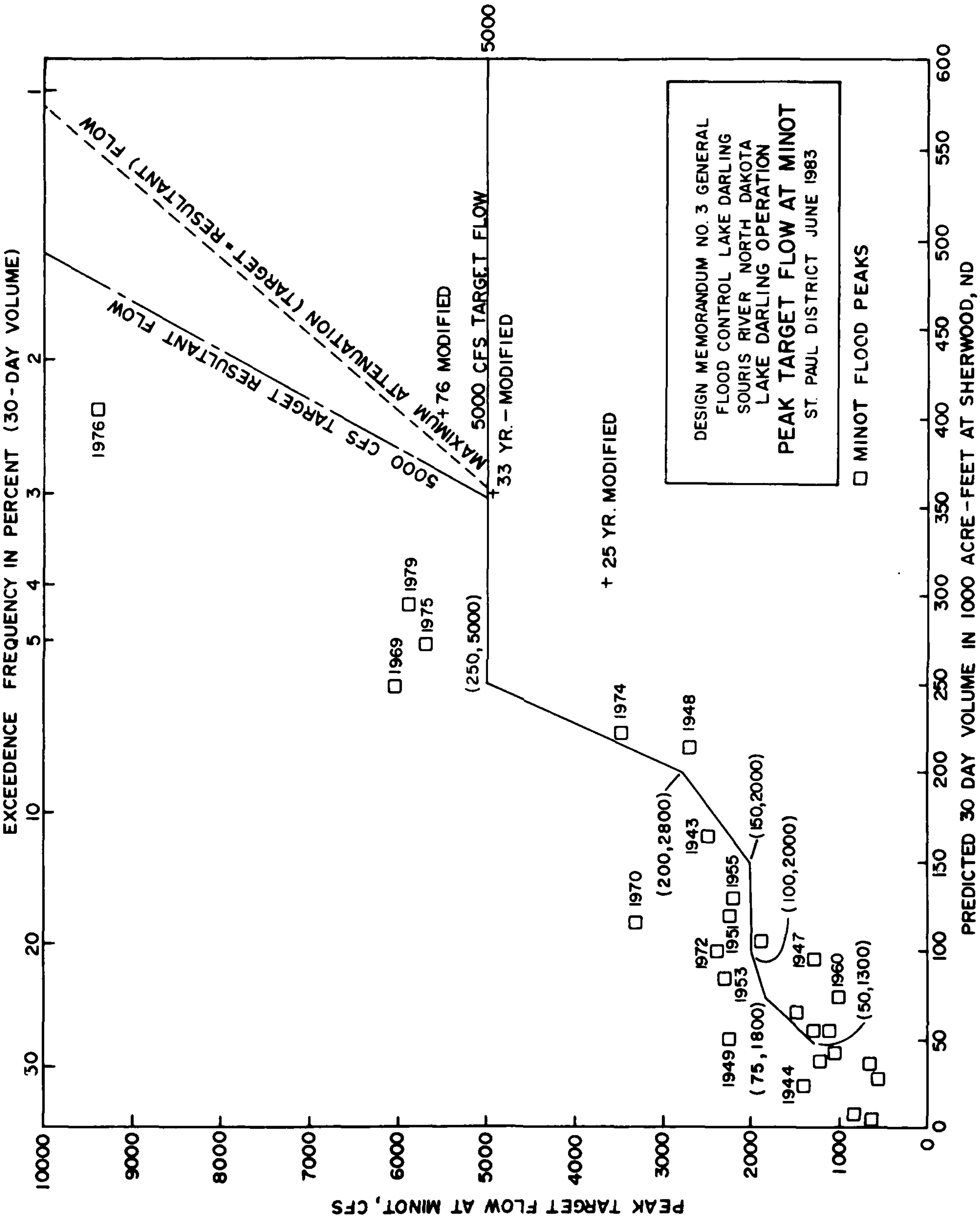

EXCEEDENCE FREQUENCY IN PERCENT (30-DAY VOLUME)
PEAK TARGET FLOW AT MINOT, CFS
PREDICTED 30 DAY VOLUME IN 1000 ACRE-FEET AT SHERWOOD, ND
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL LAKE DARLING
SOURIS RIVER NORTH DAKOTA
LAKE DARLING OPERATION
PEAK TARGET FLOW AT MINOT
ST. PAUL DISTRICT JUNE 1983
MINOT FLOOD PEAKS
MAXIMUM ATTENUATION (TARGET = RESULTANT) FLOW
5000 CFS TARGET RESULTANT FLOW
5000 CFS TARGET FLOW
+ 76 MODIFIED
+ 33 YR. - MODIFIED
+ 25 YR. MODIFIED
(250,5000)
(200,2800)
(150,2000)
(100,2000)
(75,1800)
(50,1300)
1976
1979
1975
1969
1974
1948
1943
1970
1955
1951
1972
1953
1947
1960
1949
1944

EXHIBIT 6

Minot vs. predicted inflow volume. After inflow exceeds target outflow, flows are adjusted at Lake Darling to allow for local flow between the dam and Minot, so as to achieve the Minot target discharge. Inflows, precipitation, and forecasts are continually monitored and analyzed during this period to achieve optimum flood control operation.

RESERVOIR DRAWDOWN

359. After the peak stage has been reached in the reservoir, the third phase, recession, has begun. Outflow is held at the target level until the pool is below elevation 1600. On or about 15 May (or when pool falls below 1600, whichever is later), releases are cut back to 2,500 cfs or a lesser discharge depending on timing, reservoir stage, and projected inflow of the flood. On or about 1 June (as long as storage pool does not exceed elevation 1600), releases are cut back to 500 cfs until the conservation pool level of 1596 is reached.

RESPONSIBILITY OF OPERATION

360. As discussed in the Operation and Maintenance section of this report, an agreement which meets the requirements of Section 7, 1944 Flood Control Act, will be drawn up prior to completion of the project. The agreement between the U.S. Fish and Wildlife Service and the Corps of Engineers will address the responsibilities of operation for each agency. In general, it is understood that the Corps of Engineers would be responsible during flood control operation and the U.S. Fish and Wildlife Service would have responsibility during non-flood operation periods. Also, there is basic agreement on the recommended operating plan (although the FWS would have preferred a fast release plan) which includes a maximum pre-flood drawdown to elevation 1591.

361. However, there are issues of concern that must be addressed prior to writing the Section 7 agreement. There are differing views on whether the Lake Darling authorization in the 1982 Energy and Water Development Appropriations Act provided for flood control operation of Lake Darling Dam to the maximum drawdown elevation of 1591. The Fish and Wildlife Service contends that the 1982 authorization did not change the previously authorized purpose of Lake Darling Dam below the present spillway elevation of 1598. Therefore, there is disagreement on whether the storage between reservoir stages 1591 and 1598 is primarily water supply storage for refuge purposes, flood control storage, or dual-use storage. Page 62 of the authorizing report for the Burlington Dam project states that flood control storage was considered to be available above elevation 1596. The Burlington phase I GDM in December 1977 for the first time proposed a 4-foot raise of Lake Darling Dam to reduce the frequency of storage behind the Burlington Dam. The operating plan for the raised Lake Darling Dam, as presented on page 62 of the GDM, states that

the drawdown level would be elevation 1591. The subsequent authorization, which directs the Corps to proceed with the 4-foot raise of Lake Darling Dam but not to work on Burlington Dam until further directed, would appear to imply the same operation for drawdown as recommended in the phase I GDM.

362. The FWS is willing to draw down to elevation 1591 for forecasts of large floods, and the Corps recognizes that the primary operating purpose of the Lake Darling Dam is to provide water supply to the Souris refuges. Therefore, any spring drawdown for floodwater storage would be done only with some certainty that the minimum inflow would be sufficient to restore the lake to the normal conservation pool level following the spring runoff. However, the issue of whether the storage between elevation 1591 and 1598 is considered flood storage is one that must be addressed because the degree of flood protection would be considerably reduced if the availability of that storage cannot be relied upon.

363. Also, definition of the period during which the Corps of Engineers would operate the dam for flood control must be determined for the Section 7 agreement. The pre-flood drawdown decisions are directly tied to the conflict of dual authorizations. Although the appropriate reservoir stages and releases for pre-flood drawdowns will be determined by a previously agreed upon set of tables, there must be a resolution of when is the latest time the Corps can be in a decision making capacity to minimize flood damages. The FWS recommends that this take place when the reservoir reaches elevation 1598 and there is 5,000 cfs or more inflow into the reservoir. The Corps position is that this is too late to begin flood control operation. On the recession side of the hydrograph, the FWS feels that when the reservoir falls to elevation 1600, they should resume operation. The Corps would prefer a lower elevation (such as 1598).

364. Local interests have requested that an advisory board be established to provide input on the dam operation. This advisory board would not be established by the Federal government. It is seen as an informal means of obtaining input on the operation of the dam and is not viewed as a day-to-day involvement, but rather as an annual review of past operation and proposed revisions to future operation. Any revisions would be within the framework of the currently agreed upon operating plan.

BENEFITS

365. Urban and rural flood reduction benefits are evaluated as the difference in average annual flood damages with and without the project. Average annual flood reduction benefits for the Lake Darling Dam project are $5,067,500 at 1983 price levels.

366. Flood damage reduction benefits for urban, rural (which includes crop and other agricultural damage), and transportation are given in

table 27. The 4-foot raise of Lake Darling Dam is estimated to reduce average annual damages from $7,373,200 without the project to $2,511,100 with the project. As indicated on the table, this project is primarily an urban protection project. Of the total average annual urban benefits, 76 percent are attributable to Minot.

367. In addition to flood control benefits, there would be future capital cost savings for replacement of transportation and fish and wildlife structures. These benefits are $366,60[illegible], at October 1983 price levels. Total project benefits are $5,464,500.

Table 27

Comparison of average annual benefits and costs

Item	Amount: October 1982 prices	Amount: Index	Amount: October 1983 prices
Average annual benefits			
Flood damage reduction	$4,526,900	1.043	$4,721,600
Urban			
Rural			
Agricultural	23,500	1.082	25,400
Other agricultural	44,200	1.005	44,400
Residential and nonresidential	211,200	1.043	220,300
Transportation	48,000	1.050	50,400
Future capital cost savings	378,700	1.050	397,600
Total	5,232,500		5,459,700
Average annual costs			4,183,200
Benefit-cost ratio			1.31

COST ALLOCATION

368. Because the project would provide no benefits other than those related to flood control, all of the costs are allocated to that purpose. Non-Federal interests would be required to share costs in accordance with the current cost-sharing policy, which is referred to as traditional local cooperation requirements. The cost of all reservoir features are to be borne by the Federal Government. However, non-Federal interests would be responsible for the traditional requirements (lands, rights-of way, and relocations) for the urban and rural improvements downstream of the reservoir necessary to accommodate planned operational releases. However, the establishment of a nationwide policy and formula for cost sharing and innovative financing beyond the traditional statutory requirements may increase the non-Federal share of project costs.

STATEMENT OF FINDINGS

369. I have reviewed and evaluated the documents concerning the proposed action, the stated views of other interested agencies and the concerned public, and other pertinent information relative to providing interim flood protection in the Souris River basin, North Dakota.

BACKGROUND

370. The proposed plan, which includes an approximately 4-foot raise of the existing Lake Darling Dam and flood control measures upstream and downstream of the dam, was authorized by the fiscal year 1982 Energy and Water Development Appropriations Act (Public Law 97-88) in response to local requests for relief from flooding. This Congressional directive supersedes a previous authorization for construction of the Burlington Dam. Features of the Lake Darling project were also included in the Burlington Dam plan; however, the Burlington Dam and Des Lacs River diversion improvements have now been placed in a deferred status because the Senate Committee directed that the Corps take no further action to construct Burlington Dam until expressly directed to do so by the committee. Since 1969, five floods have occurred on the Souris River which exceeded the current improved channel capacity of 5,000 cfs at Minot. Flood damages have largely been averted, but only through heavy expenditures of funds by the Federal Government for emergency protective works.

THE SELECTED PLAN

371. The recommended plan for flood control in the Souris basin includes several structural and nonstructural measures. Features of work considered to be included in the directive from Congress, besides the raise of Lake Darling Dam, are road and railroad relocations in the reservoir; levee improvements in the reservoir and at Velva, Sawyer, and six subdivision areas between Burlington and Minot; flood proofing of residences downstream of the dam; modification of U.S. Fish and Wildlife structures in the Upper Souris National Wildlife Refuge and the J. Clark Salyer National Wildlife Refuge; mitigation measures; compensation to Canada for altered return flows; protection measures for flooding from Gassman Coulee; and provisions for the local sponsor to provide leadership in preventing unwise development in flood plain areas below the dam.

372. The operating plan provides for regulation of Lake Darling outflow to control all floods up to the 35-year flood to a maximum of 5.000 cfs at Minot. The 5,000 release rate would be maintained until 15 May or until the pool falls below elevation 1600, whichever is later. Releases would then be cut back to a maximum of 2,500 cfs. On or about 1 June, the releases would be cut back to 500 cfs until the conservation pool of 1596 is reached.

ALTERNATIVES

373. In addition to the no-action alternative, other means of reducing flood damages in the Souris Valley were investigated previously under the Burlington Dam authorization and are summarized briefly in this design memorandum. The currently authorized project would provide an improved

level of flood protection over existing conditions, although it would be considerably lower than the level of protection that would have been provided by the Burlington Dam project or other alternatives studied. The development of project features, in accordance with the FY 1982 Appropriations Act, assumed no additional flood protection beyond this authorization.

ENVIRONMENTAL CONSIDERATIONS

374. The Lake Darling plan of operation has been developed with input from upstream and downstream interests. It appears to be the most acceptable compromise to balance adverse impacts of the operating plan among affected interests.

375. The limited increase in flood protection afforded by the dam raise and the proposed operating plan together will not significantly change hydraulic conditions below the dam from existing conditions during the more frequent floods. The degree of impact would depend on the timing and magnitude of the floods. Project impact would be more severe for the larger and later floods.

376. The most significant environmental impacts would result from extended discharges during drawdown of the Lake Darling flood pool. This would subject agricultural lands, wildlife habitat, recreation areas, and cultural resource sites below the dam to long-term inundation. Marsh management activities in both J. Clark Salyer and Upper Souris National Wildlife Refuges would be hindered by prolonged discharges.

377. Increased duration of inundation and water level fluctuations in Lake Darling would adversely affect flood plain forests, wetlands, grasslands, agricultural lands, recreation areas, and some archeological and historic sites.

378. To help offset the environmental losses attributable to the project, the plan will include several mitigatory features. The type and extent of fish and wildlife habitat, forestlands, recreation and cultural resources mitigation is being coordinated with the public concurrently with the preparation and coordination of the site-specific Lake Darling EIS. Refuge structure modifications are planned for both mitigation purposes and to accommodate the changes in operating conditions. Some recreation sites in both refuges will be upgraded to accommodate either the raise in the flood pool elevation or the increase in duration of discharge flows. There will be no fee title acquisition of lands for mitigation.

379. Project features at Renville County Park, McKinney Cemetery and Eckert Ranch constitute environmental quality measures (as well as mitigatory measures) because they would benefit EQ resources greater than the future without-project conditions.

SOCIAL CONSIDERATIONS

380. The project will improve the flood situation in Minot and other areas to a limited extent. The city of Minot will be protected against the 25-year combined Souris-Des Lacs flood or against the 35 year

Souris flood. This level of protection will not be adequate to change the legal flood plain designation, and local interests will continue to investigate additional flood control measures. In Velva and at Renville County Park, the level of flood protection will be higher (100-year), allowing removal of the floodplain designation. Small subdivisions and isolated homes along the river will be protected against the 5,000 cfs flow; in some cases, this protection will require acquisition and removal of the structures.

381. No land will be purchased for wildlife mitigation, an important element in the compromise resulting in this project. The operating plan has been designed with considerable public input to minimize negative effects of dam releases. The plans for McKinney Cemetery and Renville County Park were also modified after input from local interests. Flowage easements will be required on approximately 600 acres of downstream agricultural lands and approximately 12 downstream residences would be acquired.

ECONOMIC CONSIDERATIONS

382. Annual benefits and costs are $5,459,500 and $4,183,200, respectively, for the overall project. The benefit-cost ratio is 1.31.

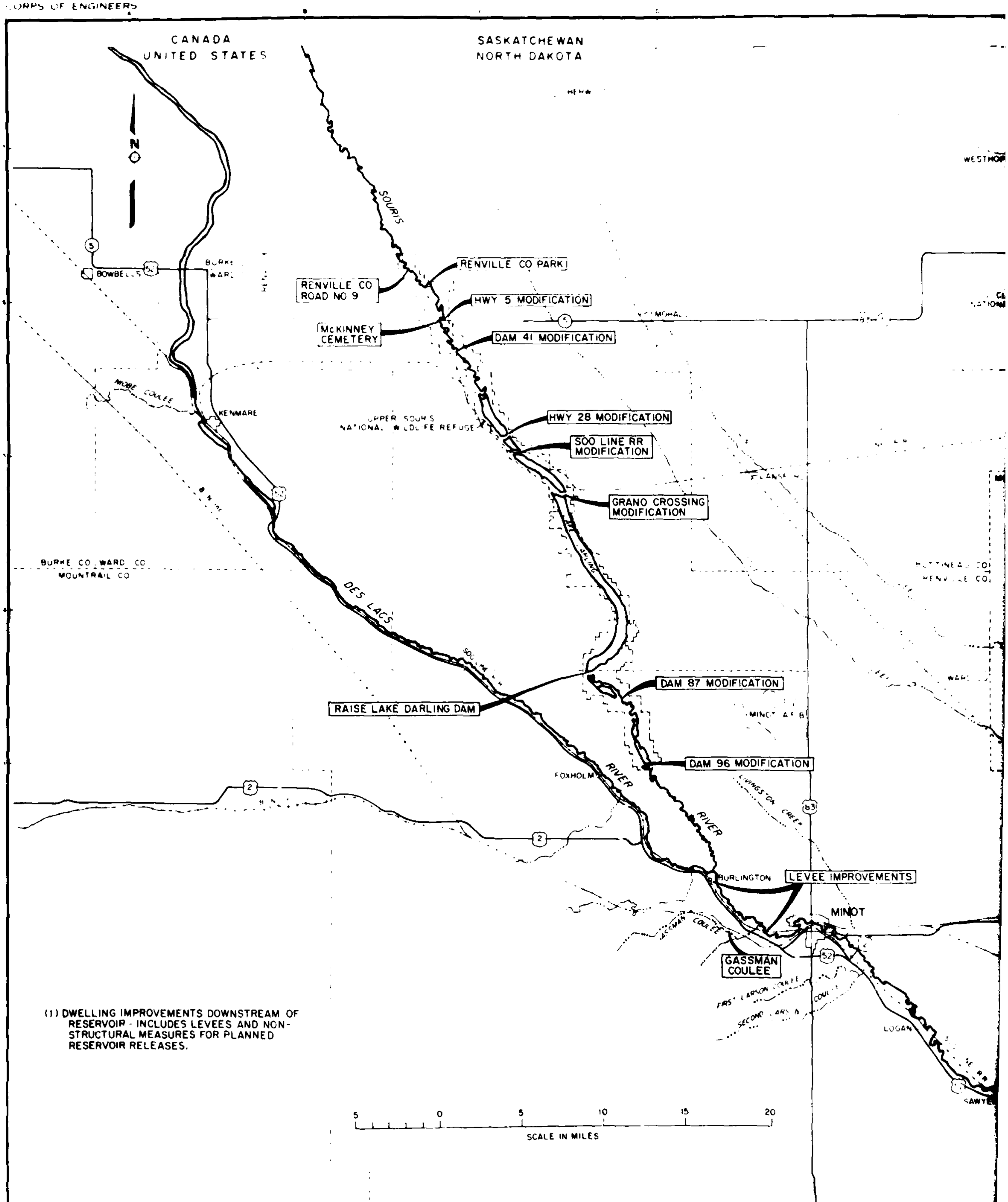
CONCLUSION

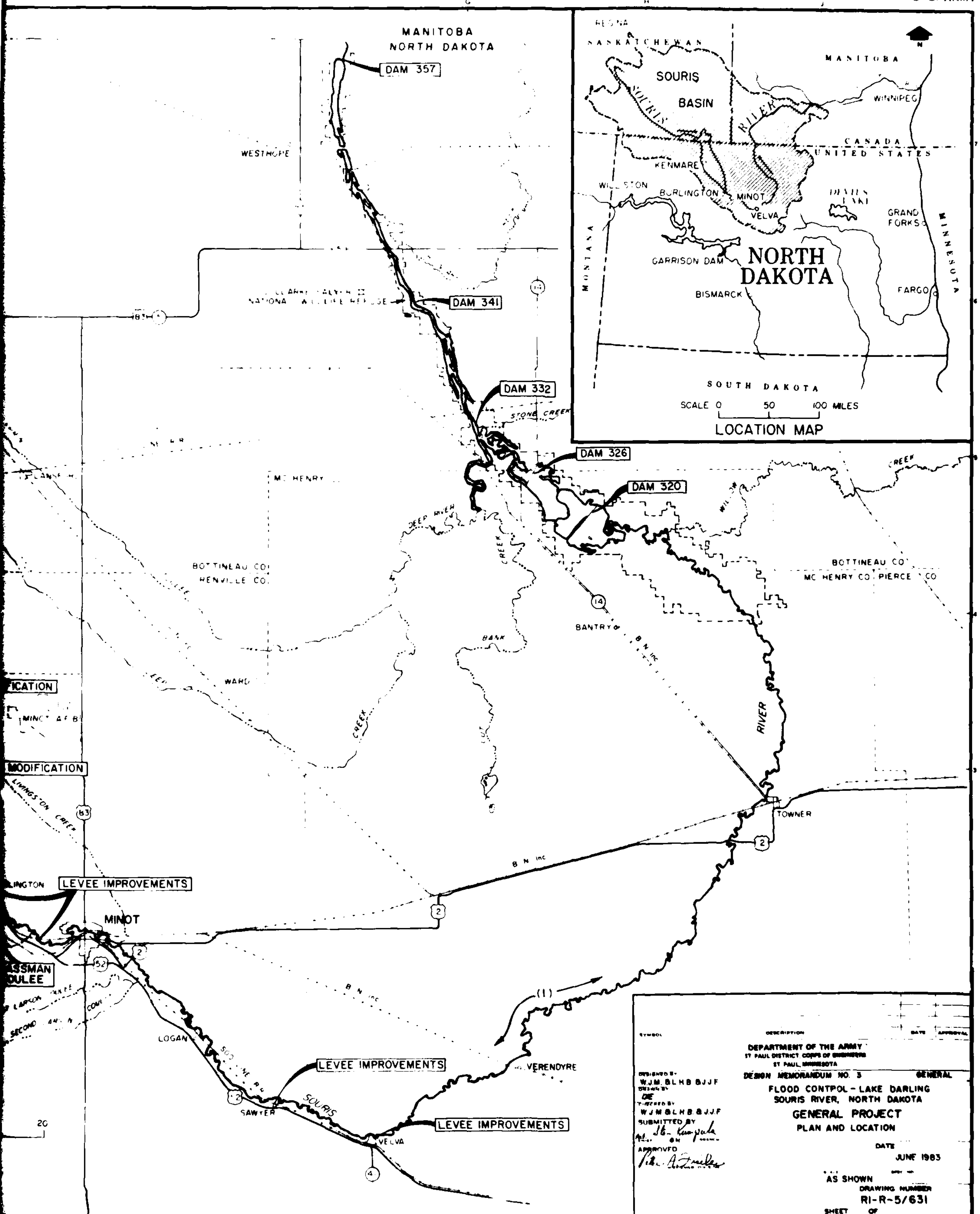
383. I find that the development of the selected plan in this general design memorandum is based on thorough analysis and investigation of various practicable alternative design schemes for achieving the desired objectives established by Congress.

RECOMMENDATIONS

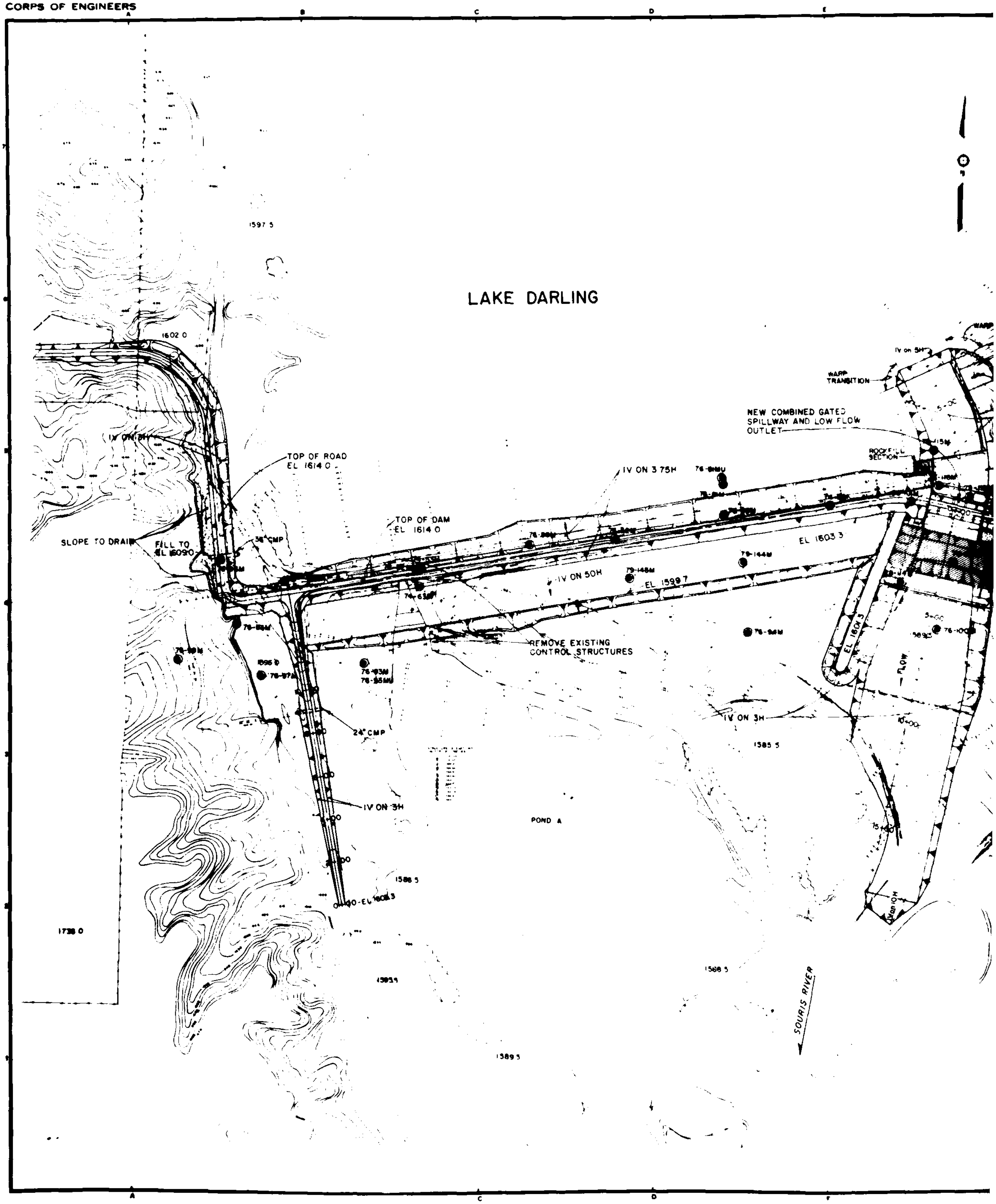
384. I recommend approval of the plan of improvement for flood control presented herein, consisting of the raise of Lake Darling Dam and operation of the the dam in a manner to minimize adverse impacts both above and below the dam; reservoir relocations and levees; levee improvements in urban areas between Burlington and Minot and at the communities of Sawyer and Velva; levees and nonstructural measures in rural areas below the reservoir; modification of refuge structures in the Upper Souris and J. Clark Salyer Refuges for operational or mitigation requirements; protection from Gassman Coulee; and compensation to Canada for altered return flows.

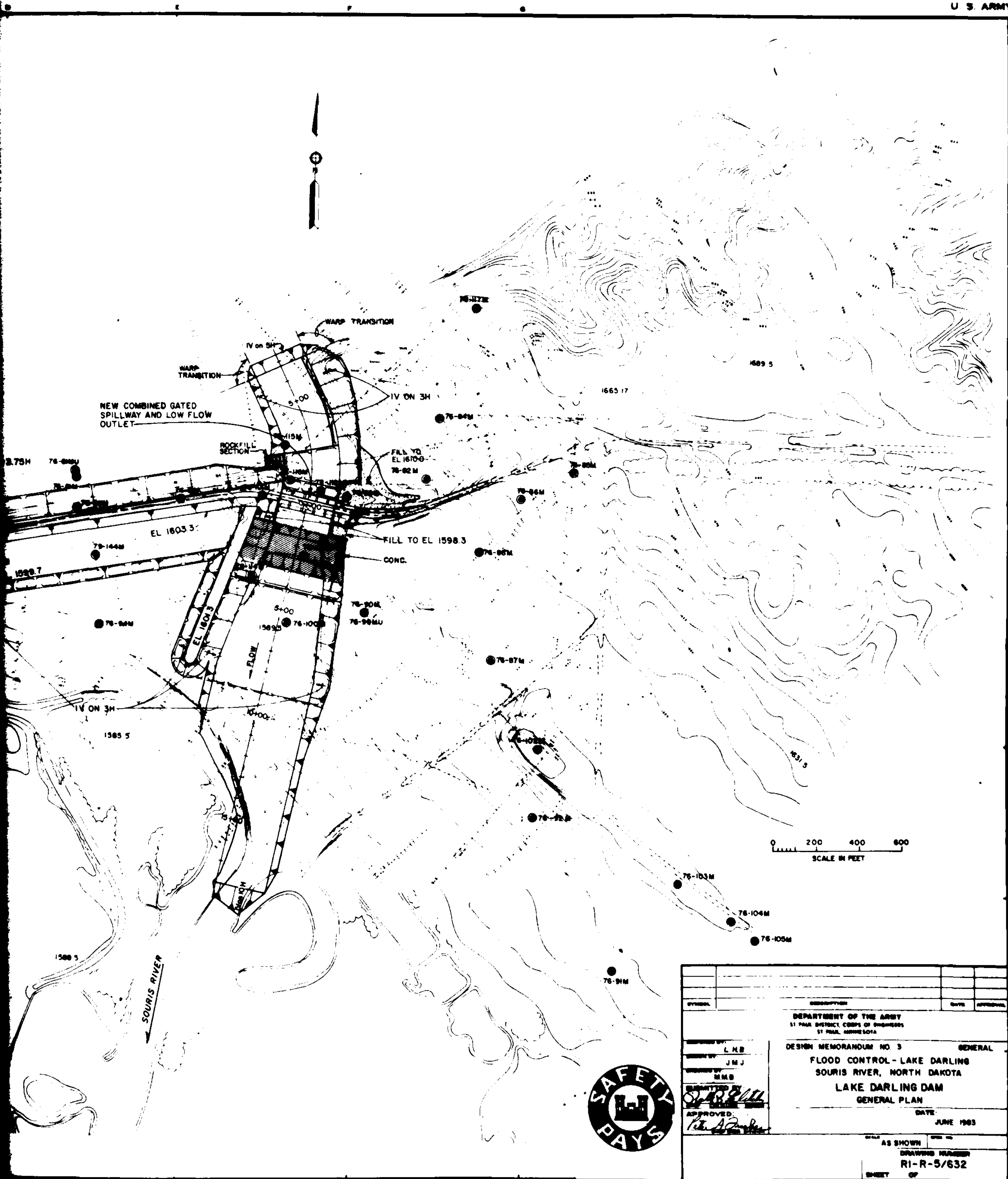
EDWARD G. RAPP
Colonel, Corps of Engineers
District Engineer


CANADA
UNITED STATES
SASKATCHEWAN
NORTH DAKOTA
N
SOURIS
RENVILLE CO PARK
RENVILLE CO ROAD NO 9
HWY 5 MODIFICATION
McKINNEY CEMETERY
DAM 41 MODIFICATION
BOWBELLS
KENMARE
UPPER SOURIS NATIONAL WILDLIFE REFUGE
HWY 28 MODIFICATION
SOO LINE RR MODIFICATION
GRANO CROSSING MODIFICATION
BURKE CO WARD CO
MOUNTRAIL CO
DES LACS
RAISE LAKE DARLING DAM
DAM 87 MODIFICATION
DAM 96 MODIFICATION
FOXHOLM
RIVER
RIVER
BURLINGTON
LEVEE IMPROVEMENTS
MINOT
GASSMAN COULEE
LOGAN
(1) DWELLING IMPROVEMENTS DOWNSTREAM OF RESERVOIR - INCLUDES LEVEES AND NON-STRUCTURAL MEASURES FOR PLANNED RESERVOIR RELEASES.
5 0 5 10 15 20
SCALE IN MILES


MANITOBA
NORTH DAKOTA
DAM 357
WESTHOPE
DAM 341
DAM 332
STONE CREEK
DAM 326
DAM 320
MC HENRY
DEEP RIVER
BOTTINEAU CO
HENVILLE CO
BOTTINEAU CO
MC HENRY CO PIERCE CO
BANTRY
B N INC
BANK
WARD
CREEK
RIVER
MODIFICATION
LIVINGSTON CREEK
TOWNER
B N INC
LEVEE IMPROVEMENTS
MINOT
LOGAN
LEVEE IMPROVEMENTS
VERENDRYE
SAWYER
SOURIS
LEVEE IMPROVEMENTS
VELVA
REGINA
SASKATCHEWAN
SOURIS
BASIN
MANITOBA
WINNIPEG
CANADA
UNITED STATES
KENMARE
BURLINGTON
MINOT
VELVA
DEVILS LAKE
GRAND FORKS
GARRISON DAM
NORTH DAKOTA
BISMARCK
FARGO
MONTANA
MINNESOTA
SOUTH DAKOTA
SCALE 0 50 100 MILES
LOCATION MAP
DEPARTMENT OF THE ARMY
ST PAUL DISTRICT CORPS OF ENGINEERS
ST PAUL, MINNESOTA
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
GENERAL PROJECT
PLAN AND LOCATION
DATE
JUNE 1983
AS SHOWN
DRAWING NUMBER
RI-R-5/631
SUBMITTED BY
APPROVED

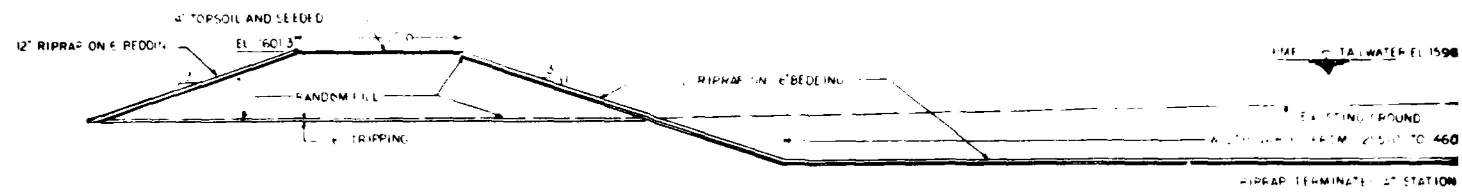
CORPS OF ENGINEERS





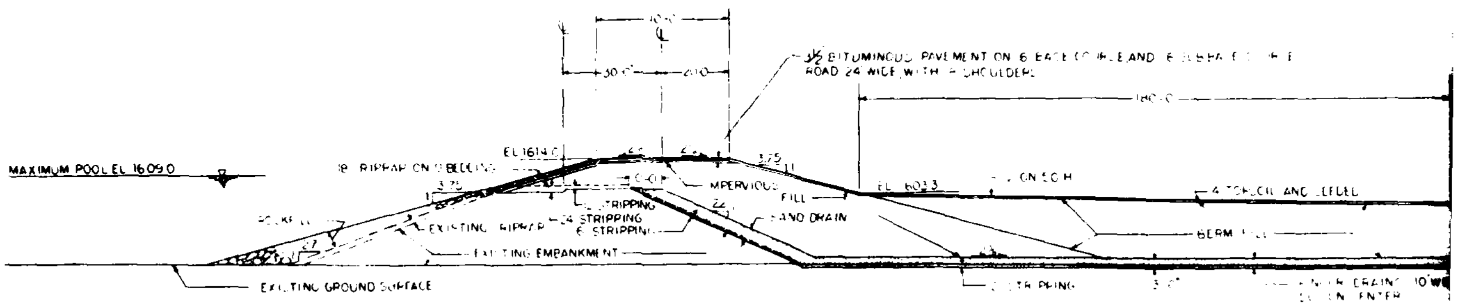
WARP TRANSITION
IV on 5H
WARP TRANSITION
IV ON 3H
NEW COMBINED GATED SPILLWAY AND LOW FLOW OUTLET
ROCKFILL SECTION
FILL TO EL 1610.0
76-82 M
76-84M
76-86M
76-88M
76-144M
EL 1603.3
FILL TO EL 1598.3
CONC.
76-96M
76-90M
76-98MU
76-100M
5+00
10+00
15+00
EL 1601.3
FLOW
76-87M
IV ON 3H
1585.5
1588.5
SOURIS RIVER
1665.17
1689.5
1631.5
76-92M
76-103M
76-104M
76-105M
76-91M
0 200 400 600
SCALE IN FEET
SAFETY PAYS
DEPARTMENT OF THE ARMY
ST PAUL DISTRICT, CORPS OF ENGINEERS
ST PAUL, MINNESOTA
L.H.B
J M J
M.M.B
APPROVED:
DESIGN MEMORANDUM NO. 3
GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
LAKE DARLING DAM
GENERAL PLAN
DATE
JUNE 1983
AS SHOWN
DRAWING NUMBER
RI-R-5/632

PLATE NO. 2



TYPICAL DISCHARGE CHANNEL SECTION

SCALE AS SHOWN BELOW
(SECTION TAKEN LOOKING U/S)



TYPICAL EMBANKMENT SECTION

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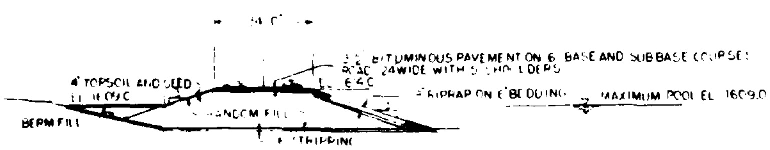
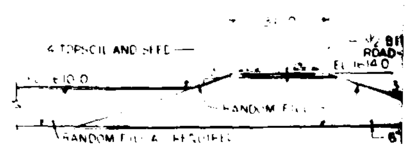


U/S TYPICAL SECTION - RIGHT ABUTMENT APPROACH ROAD

SCALE AS SHOWN ABOVE



TYPICAL SECTION - LEFT ABUTMENT APP

SCALE AS SHOWN ABOVE

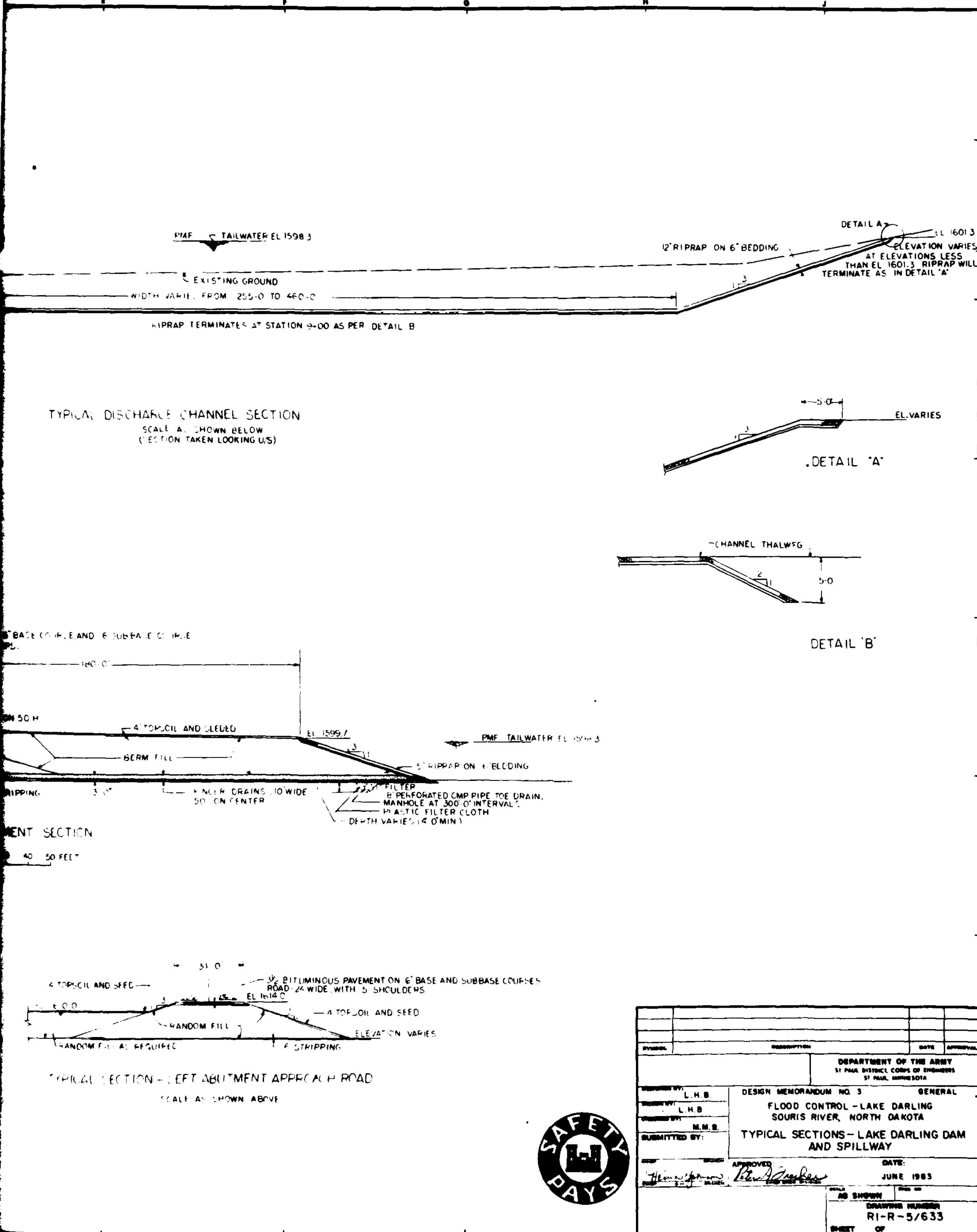
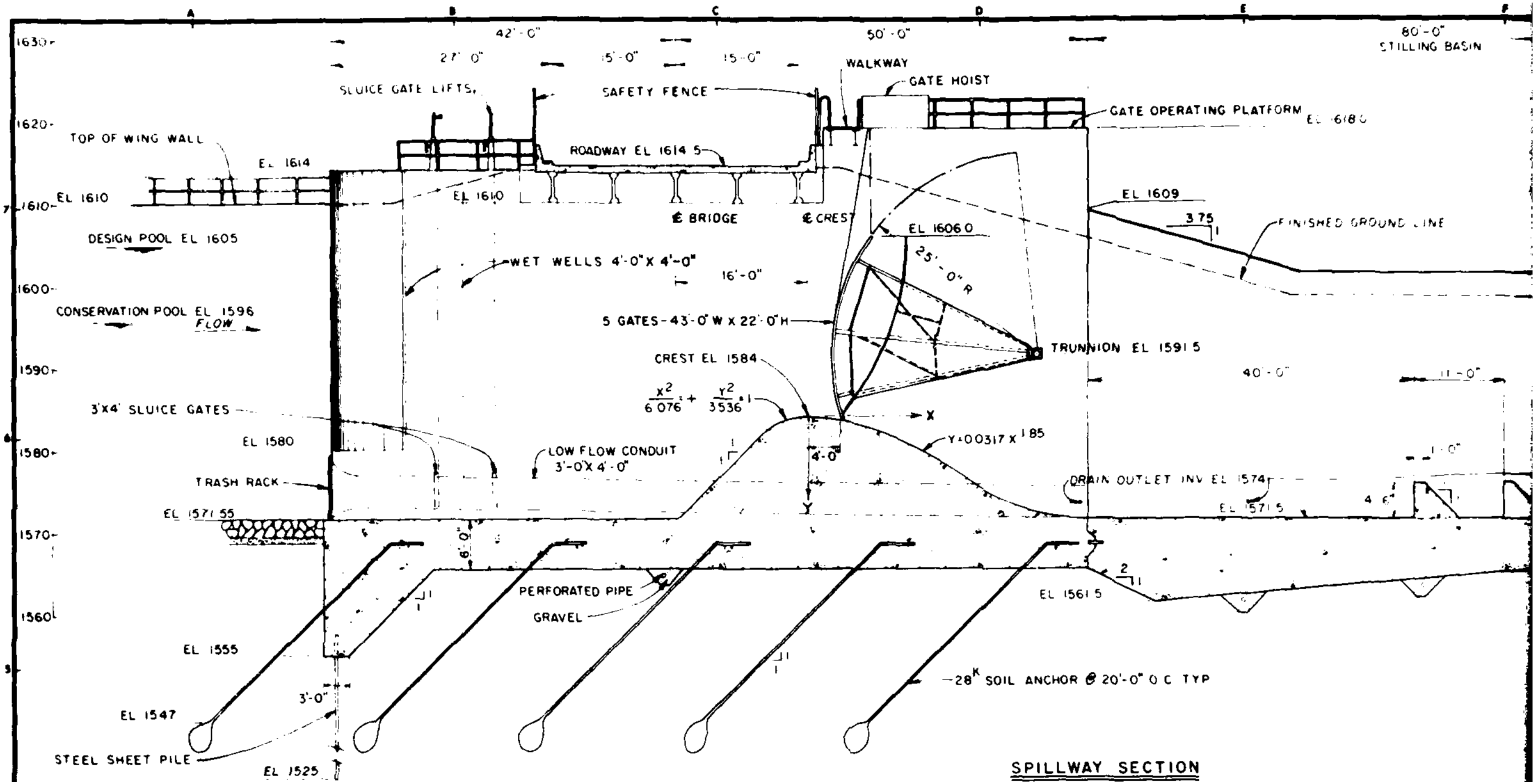

PMF TAILWATER EL 1598.3
12" RIPRAP ON 6" BEDDING
DETAIL A
EL 1601.3
ELEVATION VARIES
AT ELEVATIONS LESS THAN EL 1601.3 RIPRAP WILL TERMINATE AS IN DETAIL 'A'
EXISTING GROUND
WIDTH VARIES FROM 255-0 TO 460-0
RIPRAP TERMINATES AT STATION 9+00 AS PER DETAIL B
TYPICAL DISCHARGE CHANNEL SECTION
SCALE AS SHOWN BELOW
(SECTION TAKEN LOOKING U/S)
5.0
EL. VARIES
DETAIL 'A'
CHANNEL THALWEG
5.0
DETAIL 'B'
180.0
4" TOPSOIL AND SEEDED
EL 1599.7
BERM FILL
PMF TAILWATER EL 1598.3
5" RIPRAP ON 6" BEDDING
FINGER DRAINS 10' WIDE 50' ON CENTER
FILTER
8" PERFORATED CMP PIPE TOE DRAIN, MANHOLE AT 300.0' INTERVALS
PLASTIC FILTER CLOTH
DEPTH VARIES (4.0' MIN.)
MENT SECTION
40 50 FEET
31.0
4" TOPSOIL AND SEED
BITUMINOUS PAVEMENT ON 6" BASE AND SUBBASE COURSES ROAD 24' WIDE WITH 5' SHOULDERS
EL 1614.0
4" TOPSOIL AND SEED
RANDOM FILL
ELEVATION VARIES
RANDOM FILL AS REQUIRED
6" STRIPPING
TYPICAL SECTION - LEFT ABUTMENT APPROACH ROAD
SCALE AS SHOWN ABOVE
SAFETY PAYS
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA
L.H.B.
L.H.B.
M.M.B.
SUBMITTED BY:
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
TYPICAL SECTIONS - LAKE DARLING DAM AND SPILLWAY
APPROVED
DATE:
JUNE 1983
AS SHOWN
DRAWING NUMBER
RI-R-5/633
SHEET OF

PLATE NO. 3

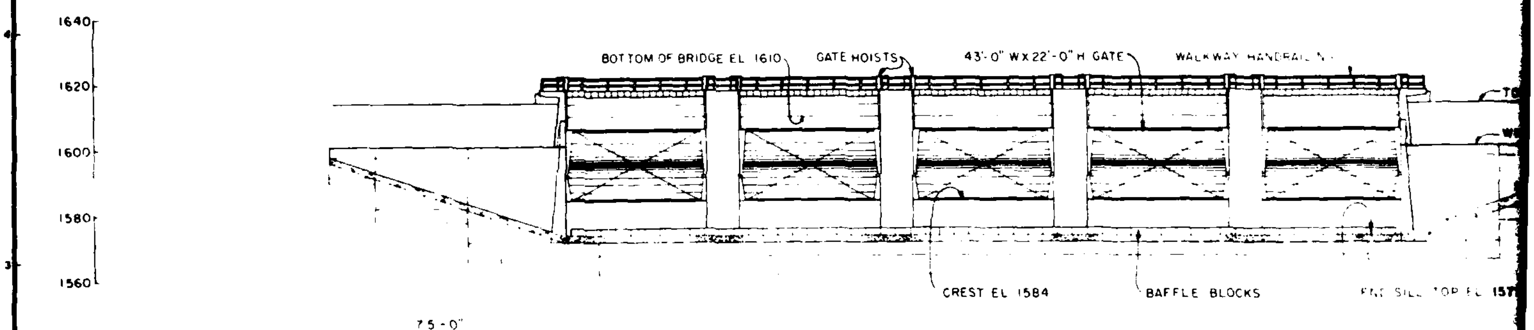
2



$$\frac{x^2}{6.076}+\frac{y^2}{3.536}=1$$

SPILLWAY SECTION

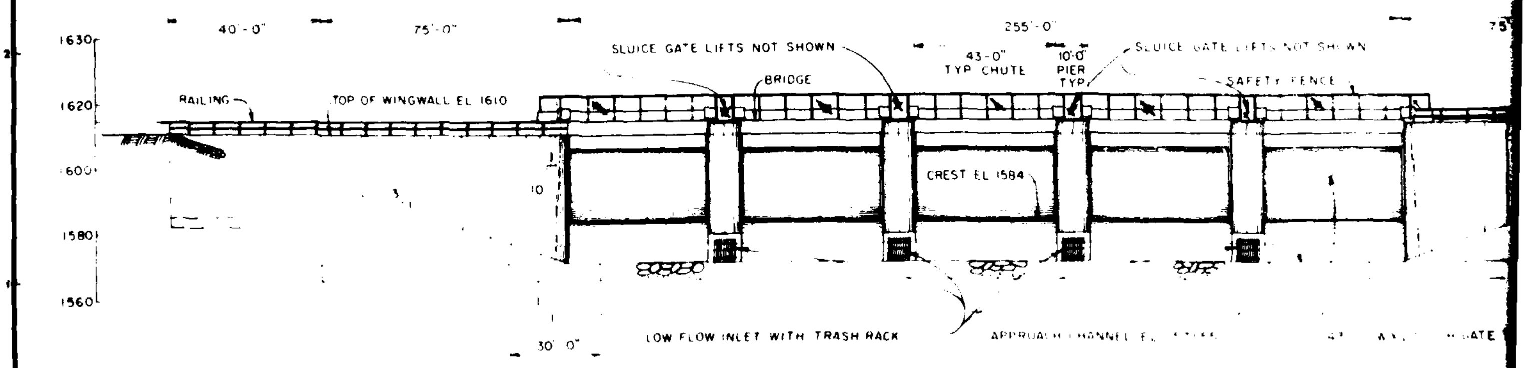
SCALE 1/8" = 1'-0"



DOWNSTREAM ELEVATION

(AT LOWER END OF STILLING BASIN)

SCALE 1" = 20'



UPSTREAM ELEVATION

SCALE 1" = 20'

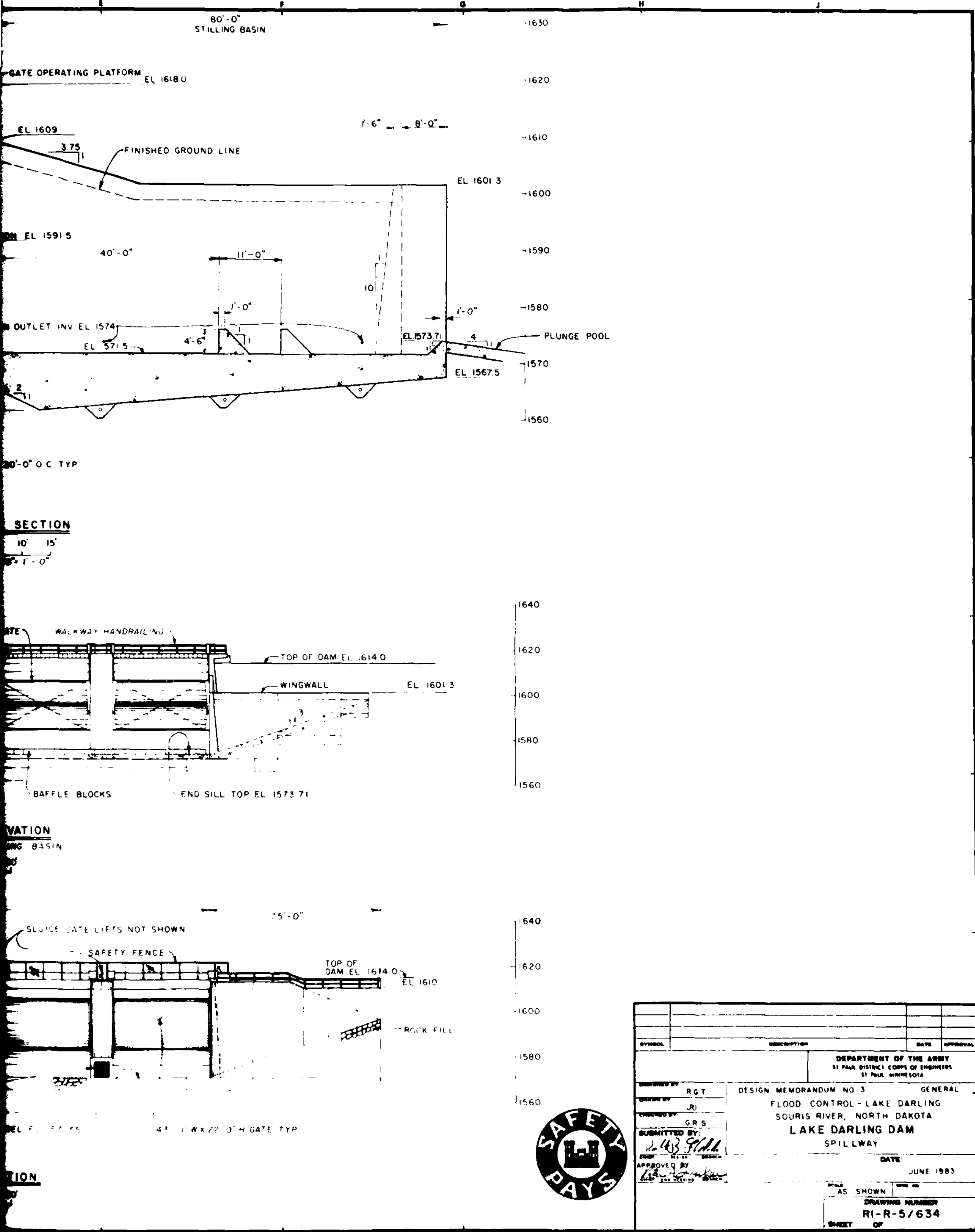
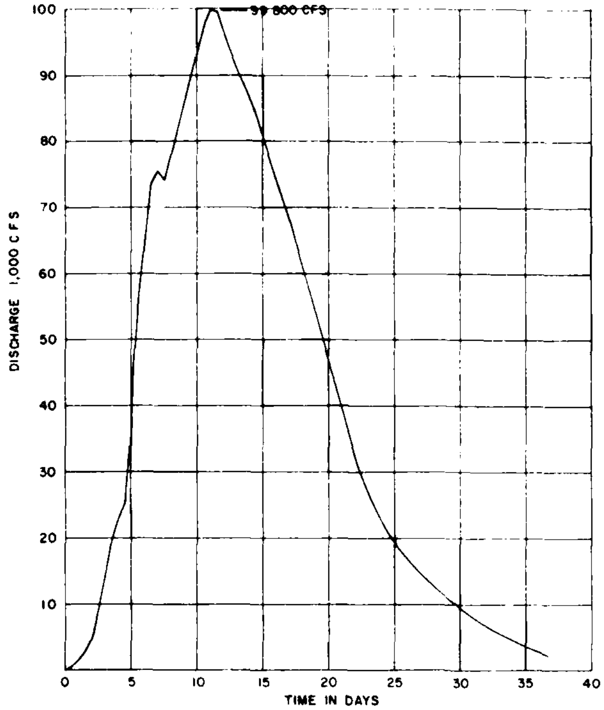
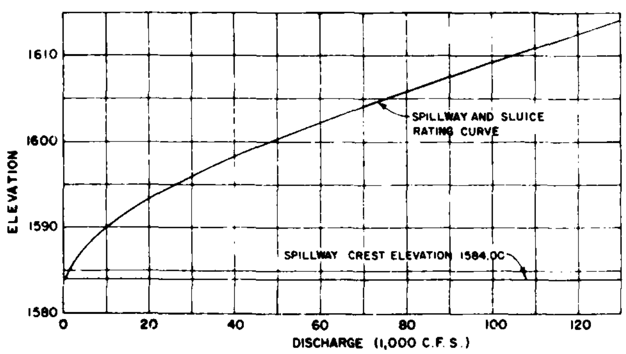
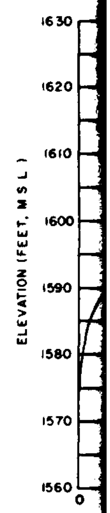

80'-0"
STILLING BASIN
GATE OPERATING PLATFORM
EL 1618.0
EL 1609
FINISHED GROUND LINE
EL 1601.3
EL 1591.5
40'-0"
11'-0"
1'-0"
OUTLET INV EL 1574
EL 1571.5
4'-6"
EL 1573.71
PLUNGE POOL
EL 1567.5
20'-0" O.C. TYP
SECTION
WALKWAY HANDRAILING
TOP OF DAM EL 1614.0
WINGWALL
EL 1601.3
BAFFLE BLOCKS
END SILL TOP EL 1573.71
VATION
75'-0"
SAFETY FENCE
TOP OF DAM EL 1614.0
EL 1610
ROCK FILL
TION
1630
1620
1610
1600
1590
1580
1570
1560
1640
SAFETY PAYS
DEPARTMENT OF THE ARMY
ST PAUL DISTRICT CORPS OF ENGINEERS
ST PAUL MINNESOTA
RGT
JU
GRS
DESIGN MEMORANDUM NO 3
GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
LAKE DARLING DAM
SPILLWAY
JUNE 1983
AS SHOWN
RI-R-5/634

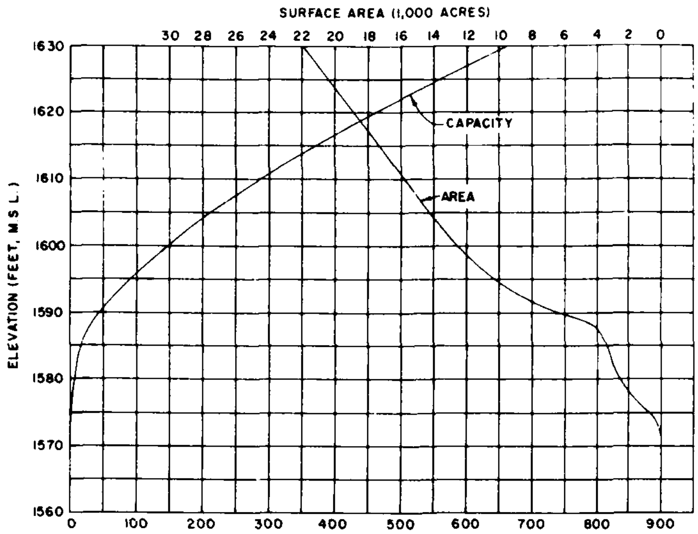
PLATE NO 4



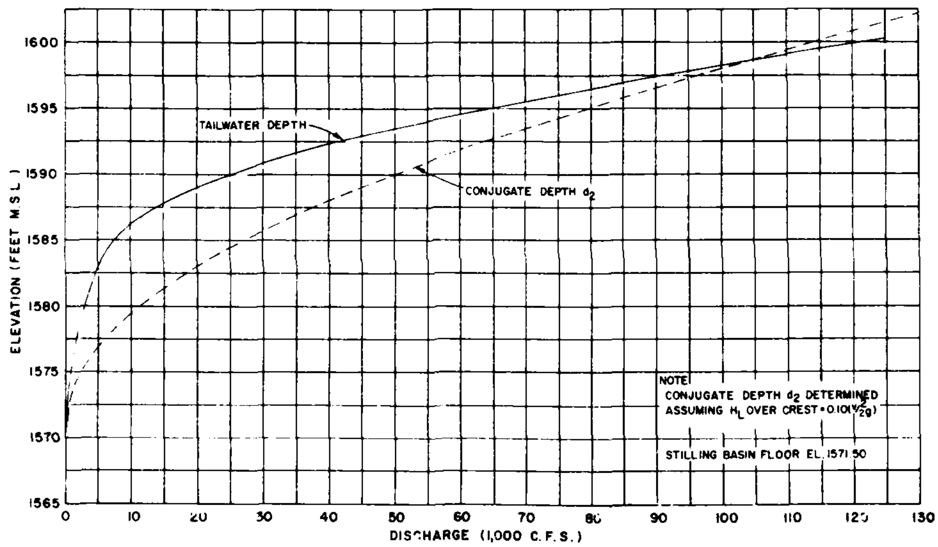
PROBABLE - MAXIMUM FLOOD
LAKE DARLING RESERVOIR







AREA-CAPACITY CURVES
LAKE DARLING RESERVOIR



LAKE DARLING TAILWATER RATING CURVE
PROPOSED CONDITIONS

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

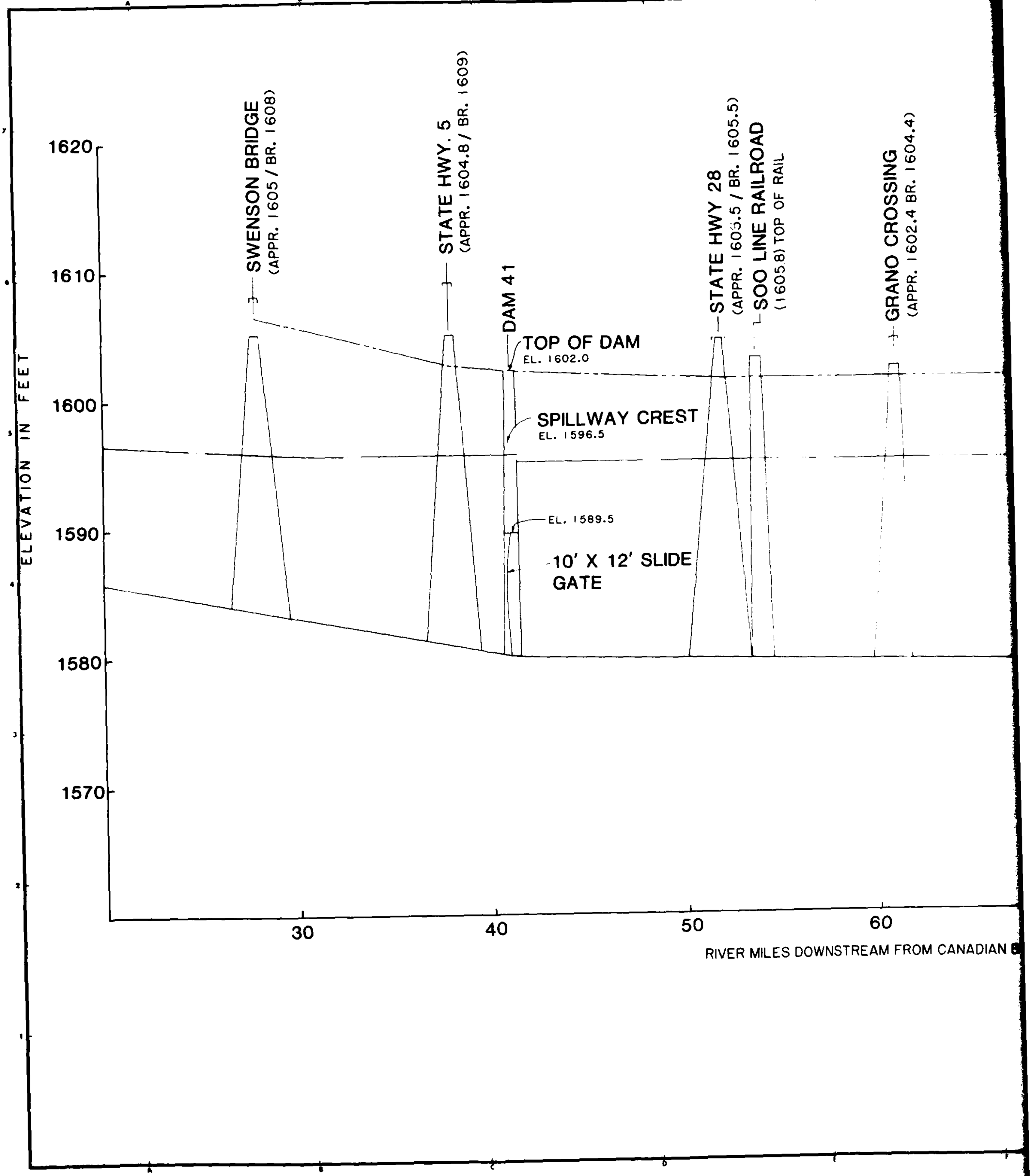
DESIGNED BY: D.J.R.
DRAWN BY: J.M.J.
CHECKED BY: J.G.M.
SUBMITTED BY:
APPROVED:

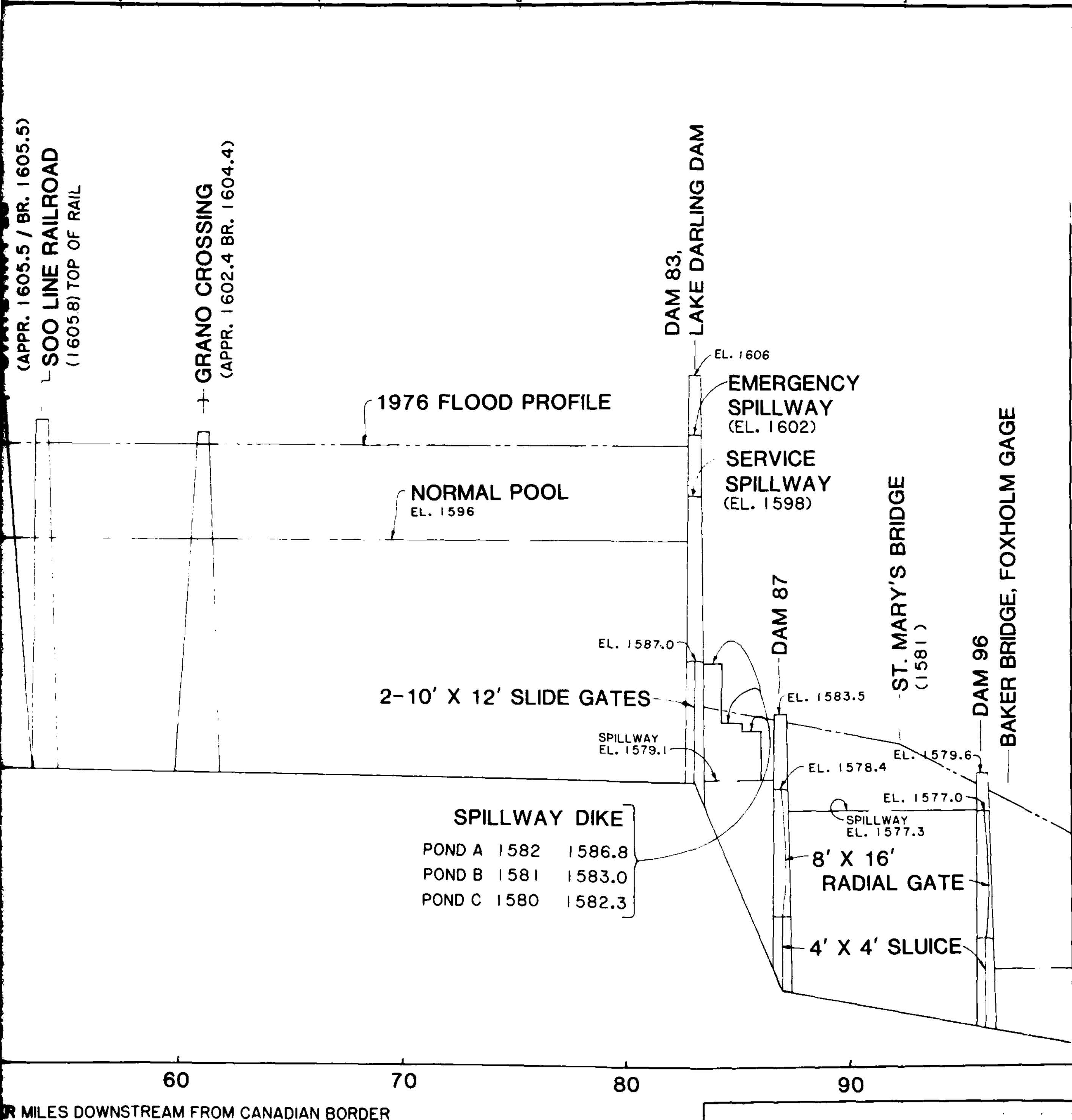
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
LAKE DARLING DAM
HYDRAULIC DATA

DATE: JUNE 1983
SCALE: AS SHOWN
DRAWING NUMBER: RI-R-5/635
SHEET OF

PLATE NO. 5

2


SWENSON BRIDGE
(APPR. 1605 / BR. 1608)
STATE HWY. 5
(APPR. 1604.8 / BR. 1609)
DAM 41
TOP OF DAM
EL. 1602.0
SPILLWAY CREST
EL. 1596.5
EL. 1589.5
10' X 12' SLIDE GATE
STATE HWY 28
SOO LINE RAILROAD
(1605.8) TOP OF RAIL
GRANO CROSSING
(APPR. 1602.4 BR. 1604.4)
ELEVATION IN FEET
1620
1610
1600
1590
1580
1570
30
40
50
60
RIVER MILES DOWNSTREAM FROM CANADIAN B



SAFETY PAYS

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: BJB
DRAWN BY: DAE
CHECKED BY: GRS
SUBMITTED BY: CHIEF DESIGN BRANCH
APPROVED:

DESIGN MEMORANDUM NO 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

SCHEMATIC PROFILE
RESERVIOR PROFILE

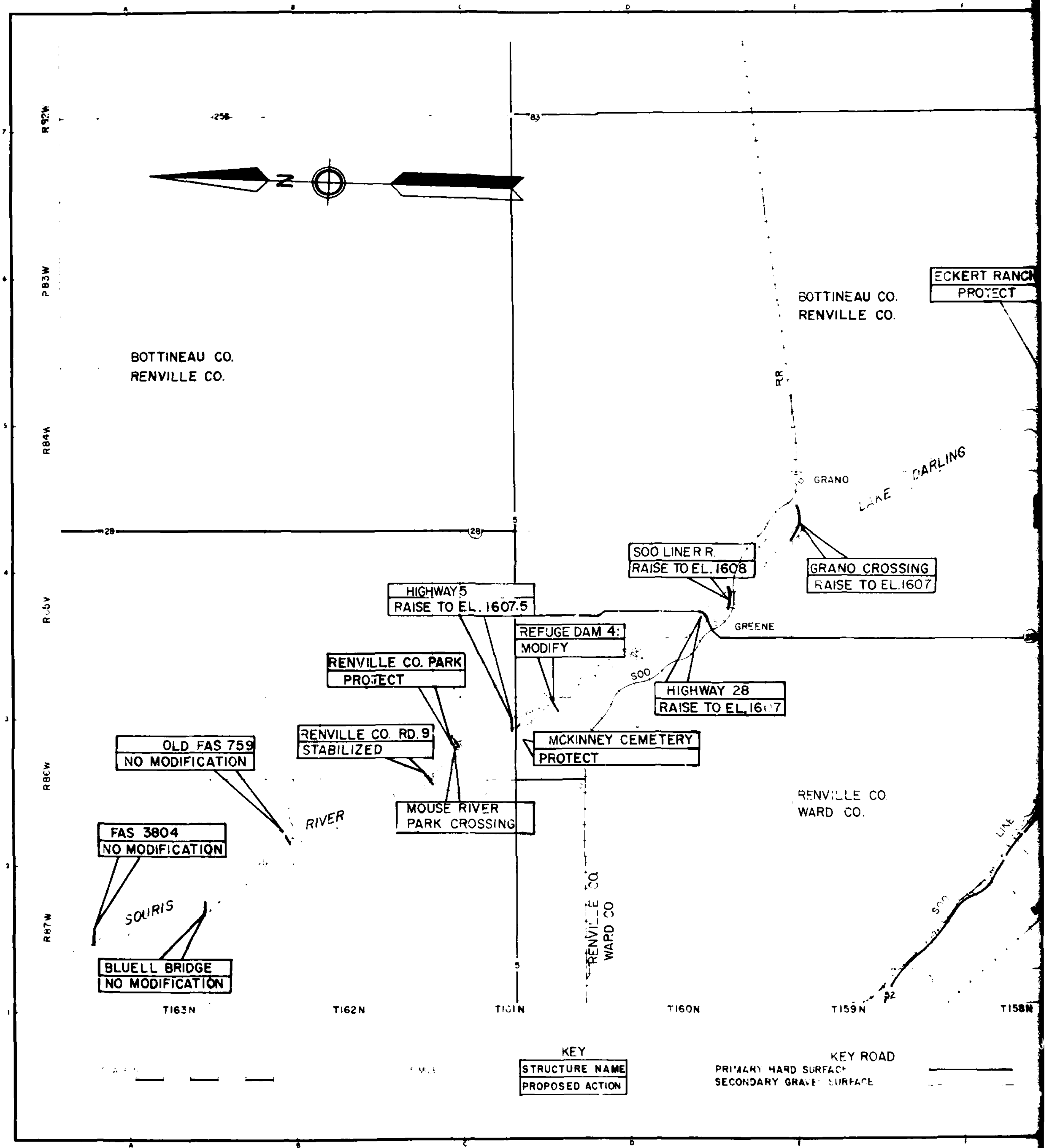
DATE JUNE 1983

AS SHOWN

DRAWING NUMBER RI-R-5/636

SHEET OF

PLATE NO 6


BOTTINEAU CO.
RENVILLE CO.
ECKERT RANCH
PROTECT
LAKE DARLING
GRANO
GRANO CROSSING
RAISE TO EL. 1607
SOO LINE R.R.
RAISE TO EL. 1608
GREENE
HIGHWAY 5
RAISE TO EL. 1607.5
REFUGE DAM 4:
MODIFY
RENVILLE CO. PARK
PROTECT
HIGHWAY 28
RAISE TO EL. 16?7
RENVILLE CO. RD. 9
STABILIZED
MCKINNEY CEMETERY
PROTECT
OLD FAS 759
NO MODIFICATION
MOUSE RIVER
PARK CROSSING
RENVILLE CO.
WARD CO.
FAS 3804
NO MODIFICATION
SOURIS
RIVER
BLUELL BRIDGE
NO MODIFICATION
T163N
T162N
T161N
T160N
T159N
T158N
R82W
R83W
R84W
R85W
R86W
R87W
KEY
STRUCTURE NAME
PROPOSED ACTION
KEY ROAD
PRIMARY HARD SURFACE
SECONDARY GRAVEL SURFACE

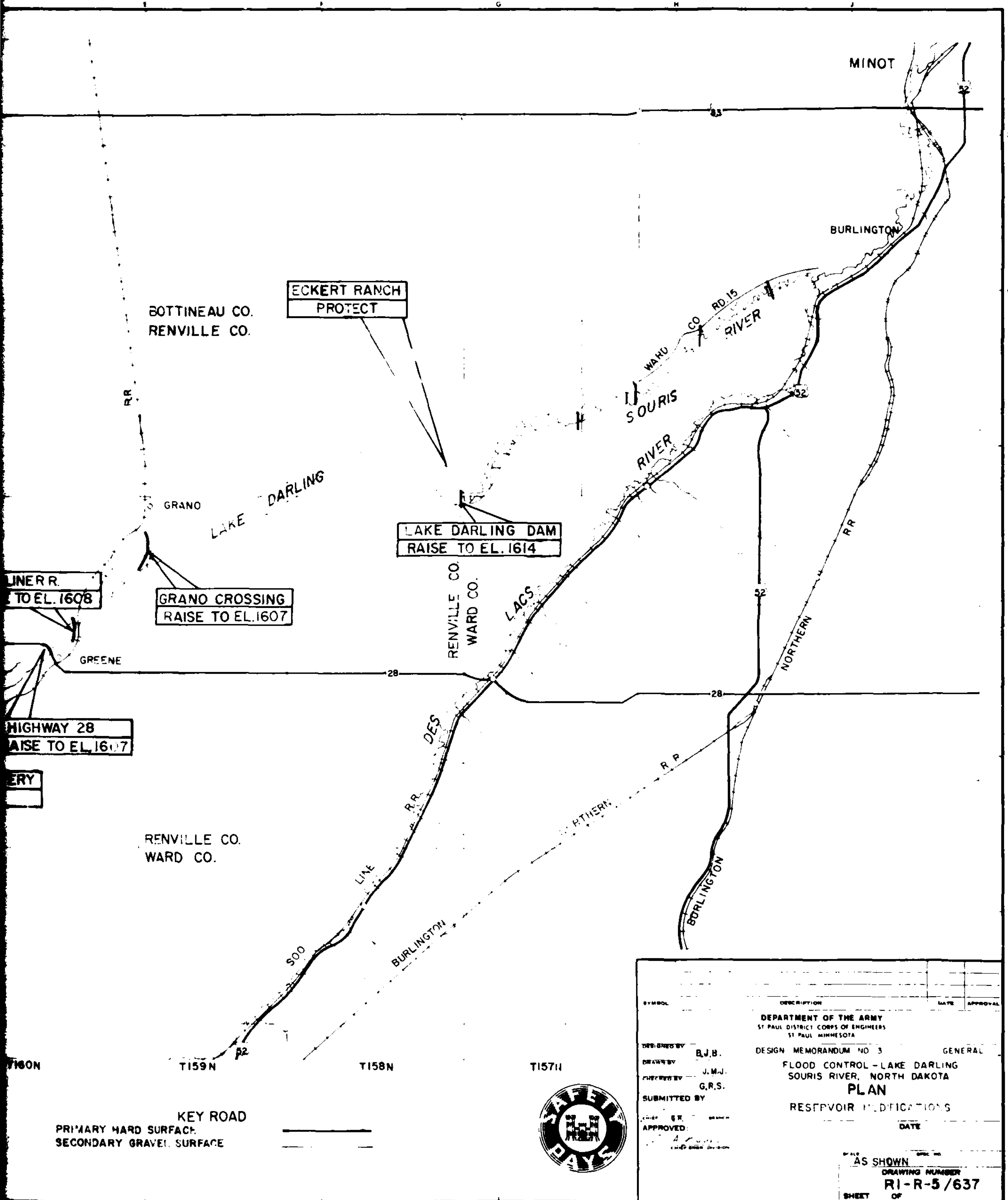
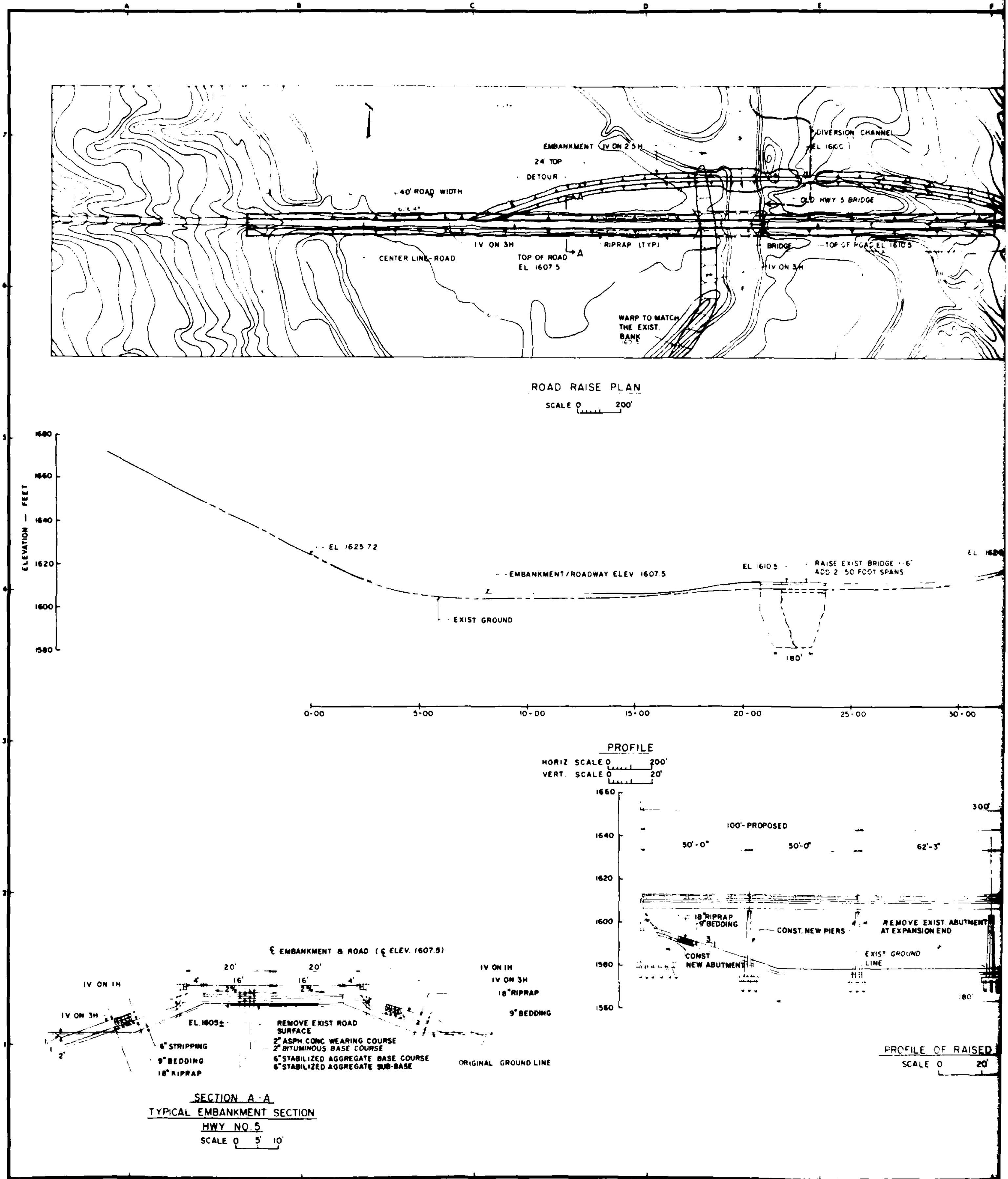
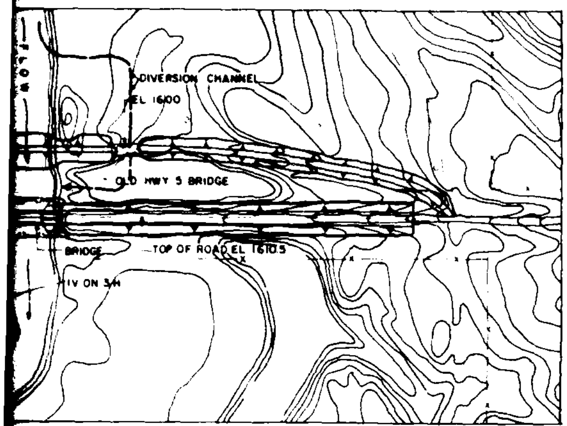
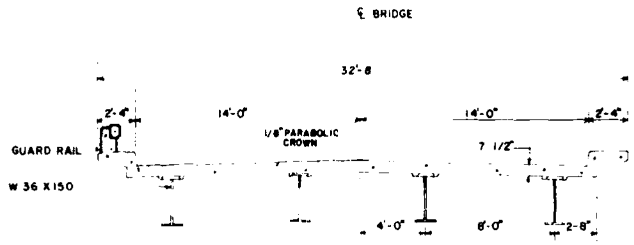

MINOT
BURLINGTON
BOTTINEAU CO.
RENVILLE CO.
ECKERT RANCH
PROTECT
WARD CO. RD. 15
SOURIS RIVER
RIVER
GRANO
LAKE DARLING
LAKE DARLING DAM
RAISE TO EL. 1614
GRANO CROSSING
RAISE TO EL. 1607
LINE R.R.
TO EL. 1608
GREENE
RENVILLE CO.
WARD CO.
DES LACS
HIGHWAY 28
RAISE TO EL. 1607
RENVILLE CO.
WARD CO.
SOO LINE R.R.
BURLINGTON
NORTHERN R.R.
T160N
T159N
T158N
T157N
KEY ROAD
PRIMARY HARD SURFACE
SECONDARY GRAVEL SURFACE
SAFETY PAYS
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT CORPS OF ENGINEERS
ST. PAUL MINNESOTA
DESIGNED BY B.J.B.
DRAWN BY J.M.J.
CHECKED BY G.R.S.
SUBMITTED BY
APPROVED
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
PLAN
RESERVOIR MODIFICATIONS
DATE
AS SHOWN
DRAWING NUMBER
RI-R-5/637
SHEET OF

PLATE NO. 7

2

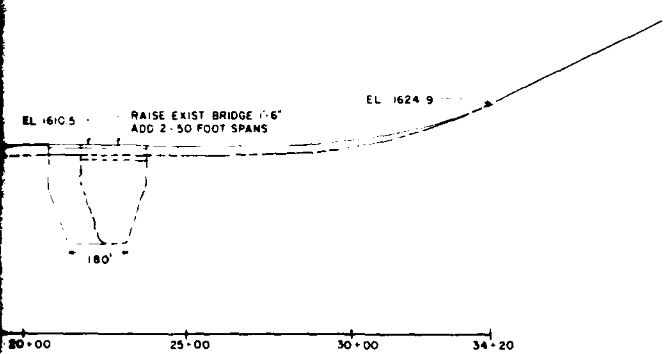

DIVERSION CHANNEL
EL 1610
EMBANKMENT 1V ON 2.5H
24' TOP
DETOUR
40' ROAD WIDTH
OLD HWY 5 BRIDGE
1V ON 3H
RIPRAP (TYP)
BRIDGE
TOP OF ROAD EL 1610.5
CENTER LINE-ROAD
TOP OF ROAD
EL 1607.5
A
1V ON 3H
WARP TO MATCH
THE EXIST.
BANK
ROAD RAISE PLAN
SCALE 0 200'
ELEVATION — FEET
1680
1660
1640
1620
1600
1580
EL 1625.72
EMBANKMENT/ROADWAY ELEV 1607.5
EL 1610.5
RAISE EXIST BRIDGE 6'
ADD 2 50 FOOT SPANS
EXIST GROUND
180'
0+00
5+00
10+00
15+00
20+00
25+00
30+00
PROFILE
HORIZ SCALE 0 200'
VERT. SCALE 0 20'
1660
1640
1620
1600
1580
1560
100'-PROPOSED
50'-0"
50'-0"
62'-3"
300'
18" RIPRAP
9" BEDDING
CONST. NEW PIERS
REMOVE EXIST. ABUTMENT
AT EXPANSION END
CONST
NEW ABUTMENT
EXIST GROUND
LINE
180'
PROFILE OF RAISED
SCALE 0 20'
℄ EMBANKMENT & ROAD (℄ ELEV. 1607.5)
20'
20'
16'
16'
4'
4'
2%
2%
1V ON 1H
1V ON 1H
1V ON 3H
1V ON 3H
18" RIPRAP
9" BEDDING
EL. 1605±
REMOVE EXIST ROAD
SURFACE
2" ASPH CONC WEARING COURSE
2" BITUMINOUS BASE COURSE
6" STABILIZED AGGREGATE BASE COURSE
6" STABILIZED AGGREGATE SUB-BASE
6" STRIPPING
9" BEDDING
18" RIPRAP
2'
ORIGINAL GROUND LINE
SECTION A-A
TYPICAL EMBANKMENT SECTION
HWY NO. 5
SCALE 0 5' 10'

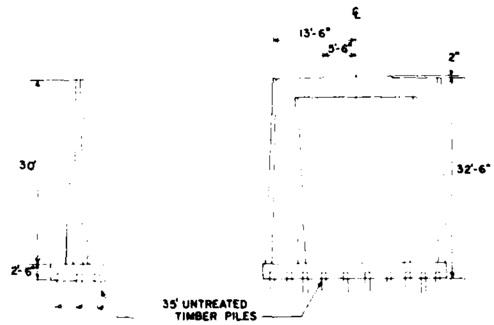




TYPICAL BRIDGE CROSS SECTION

SCALE 12" 0 5

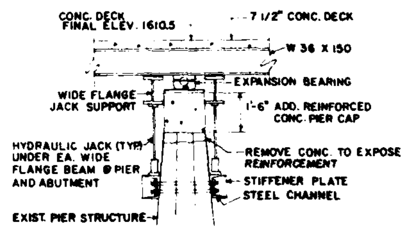




END VIEW

ELEVATION NEW PIER

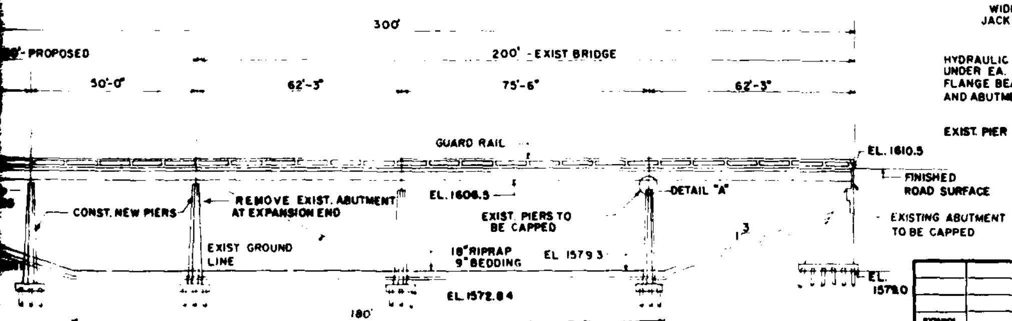
SCALE: 0 4 8



DETAIL "A"

BRIDGE RAISE STATE HWY 5

N.T.S.



PROFILE OF RAISED BRIDGE

SCALE 0 20' 40'

SAFETY PAYS

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: MLC
DRAWN BY: MLC
CHECKED BY: GRS MLC
SUBMITTED BY:
APPROVED:
CHIEF, ENGINEERING DIVISION

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL — LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
HIGHWAY 5
RELOCATION

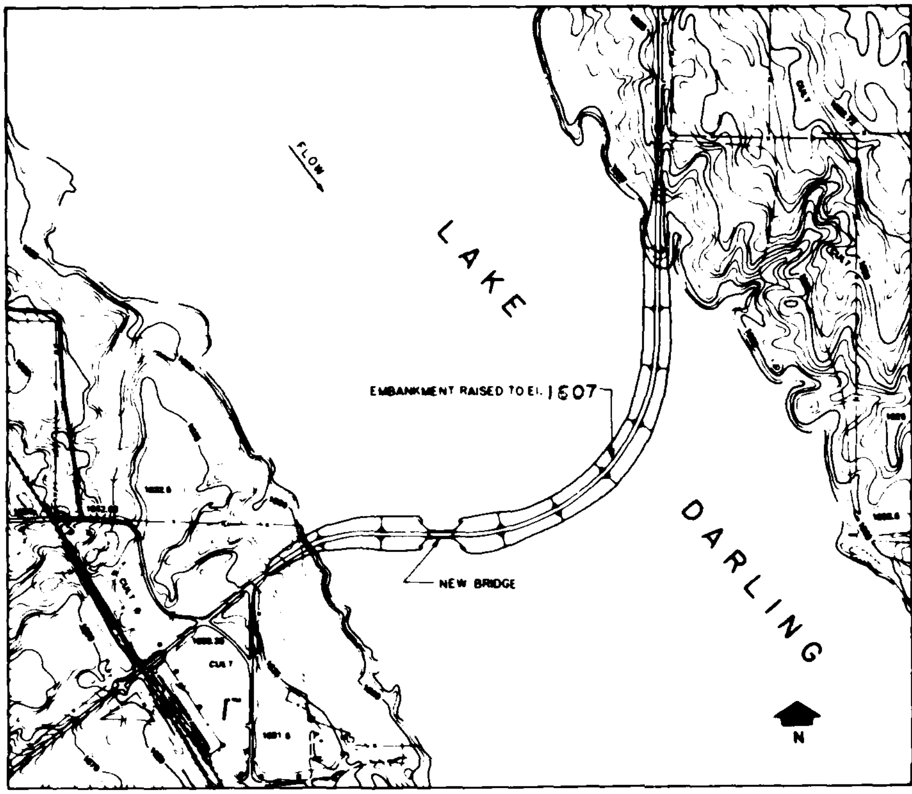
DATE: JUNE 1983

SCALE: AS SHOWN

DRAWING NUMBER: RI-R-5/638

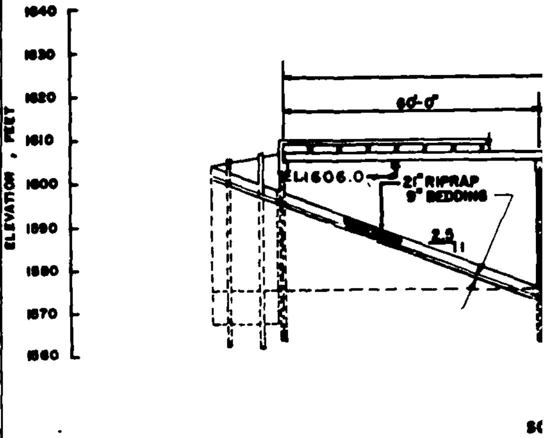
SHEET OF

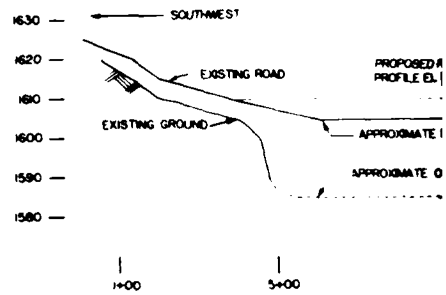
PLATE NO 8

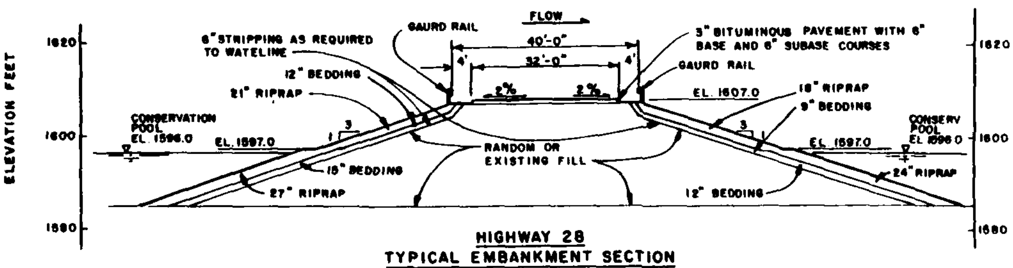


PLAN

SCALE 0 400 800 FEET





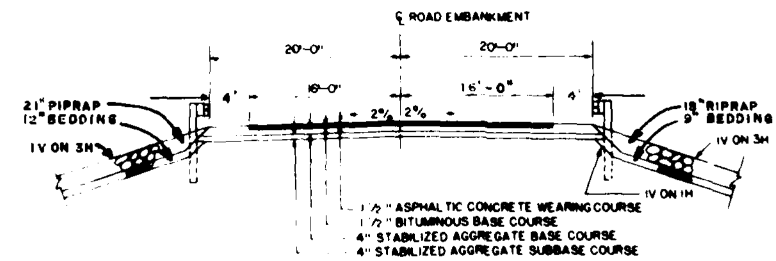


HIGHWAY 28

TYPICAL EMBANKMENT SECTION

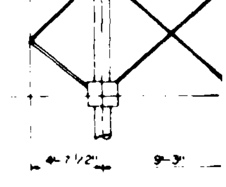
20' 0 20'

SCALE IN FEET



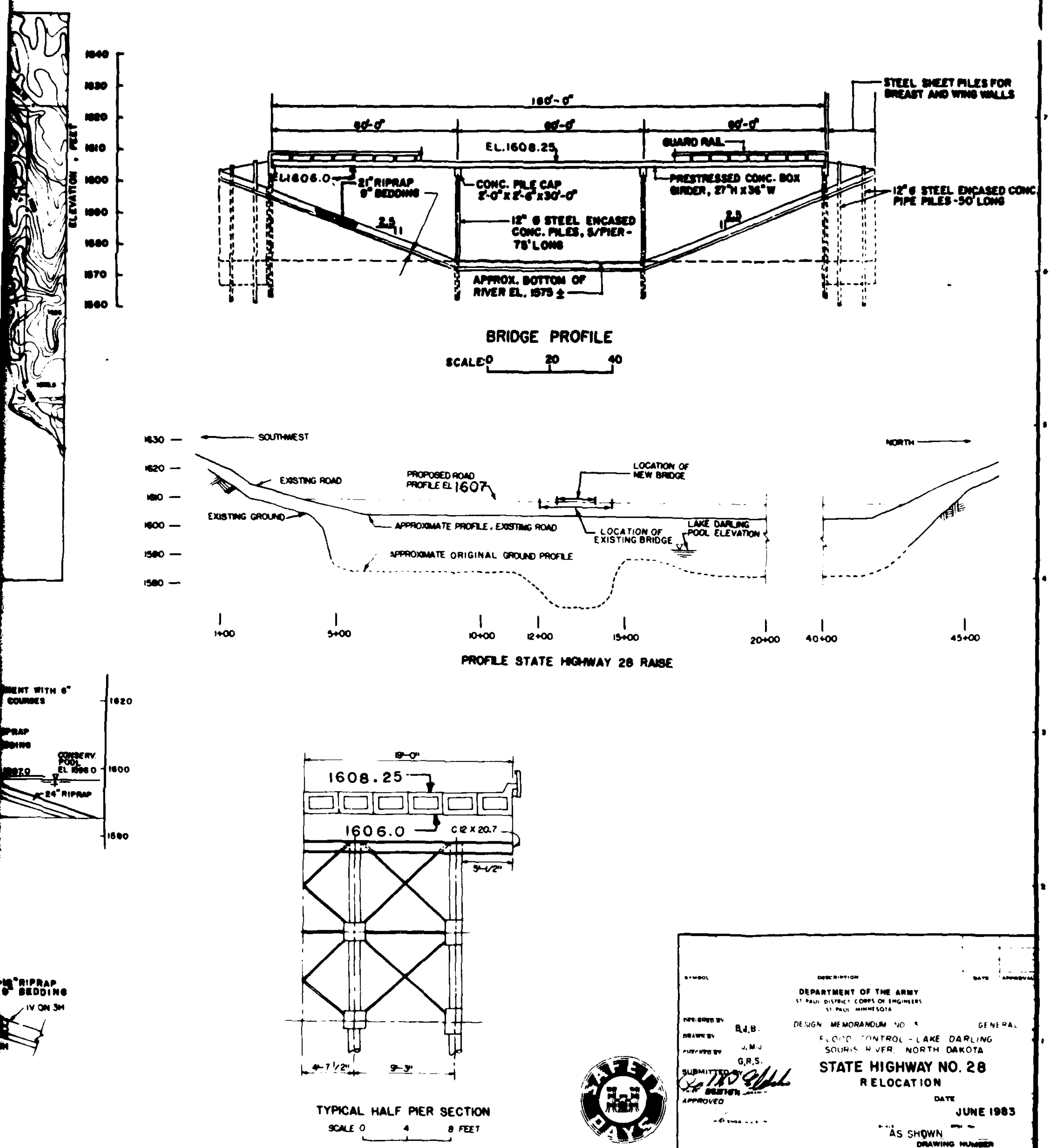
NOT TO SCALE

DETAIL A



TYPICAL HALF PIER

SCALE 0 4



DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY B.J.B.
DRAWN BY J.M.J.
CHECKED BY G.R.S.

DESIGN MEMORANDUM NO. 5 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

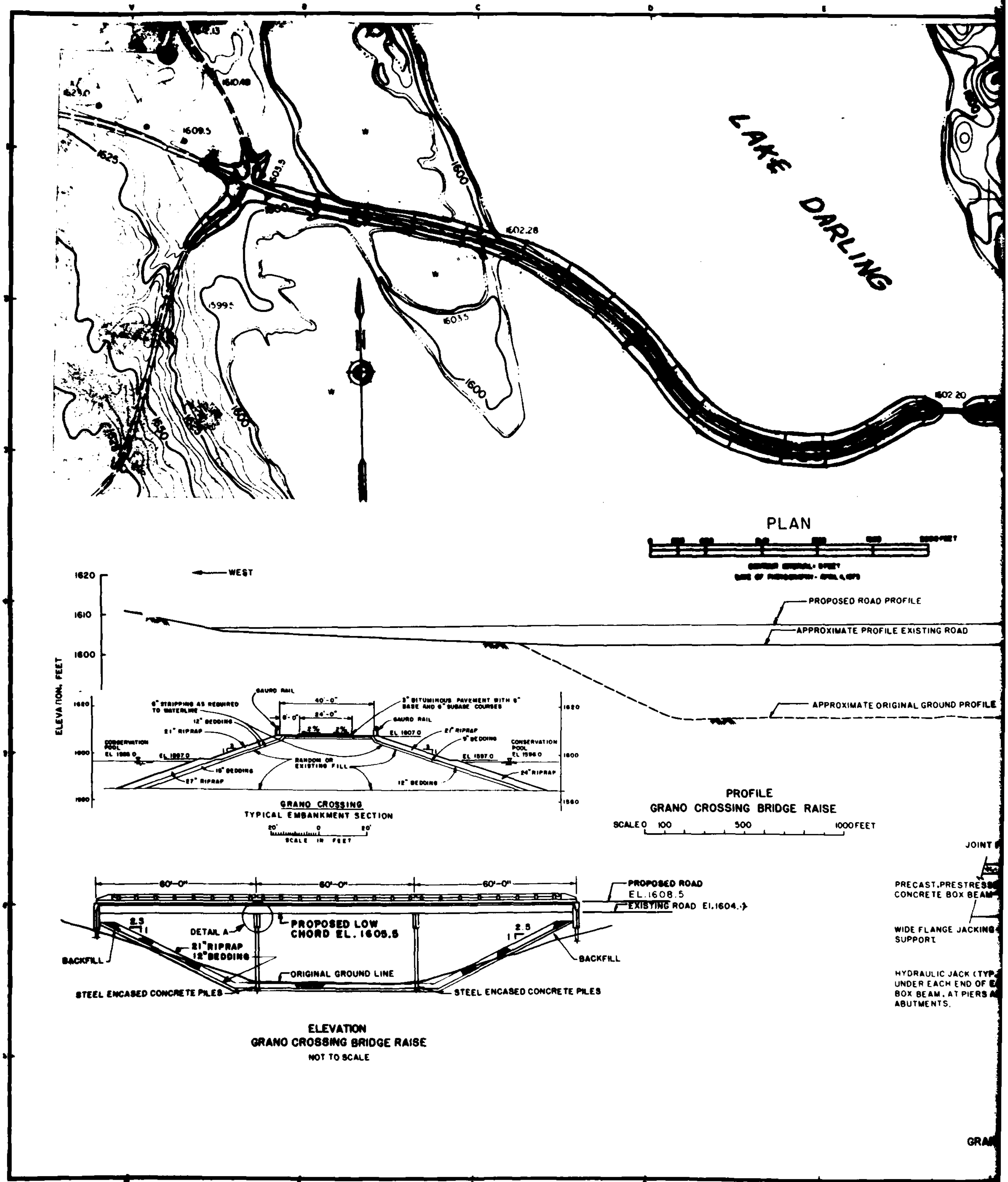
STATE HIGHWAY NO. 28
RELOCATION

DATE JUNE 1983

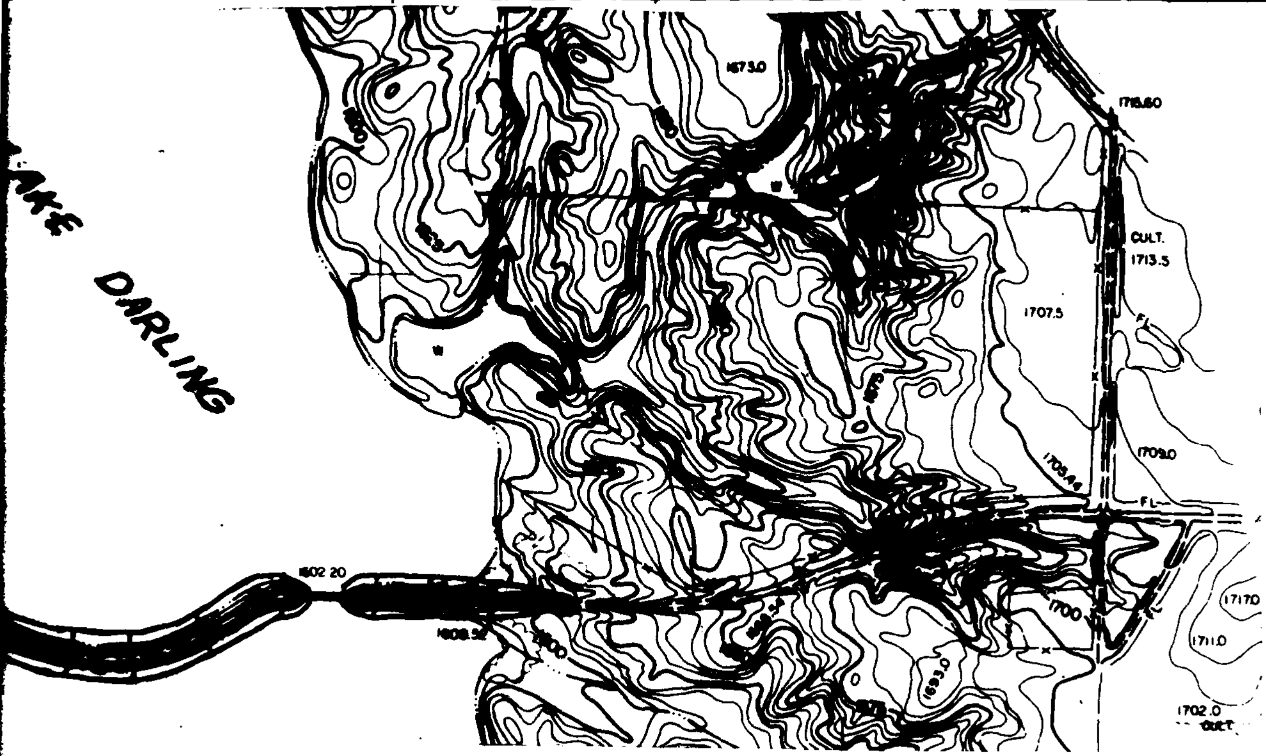
SCALE AS SHOWN

DRAWING NUMBER RI-R-5/639

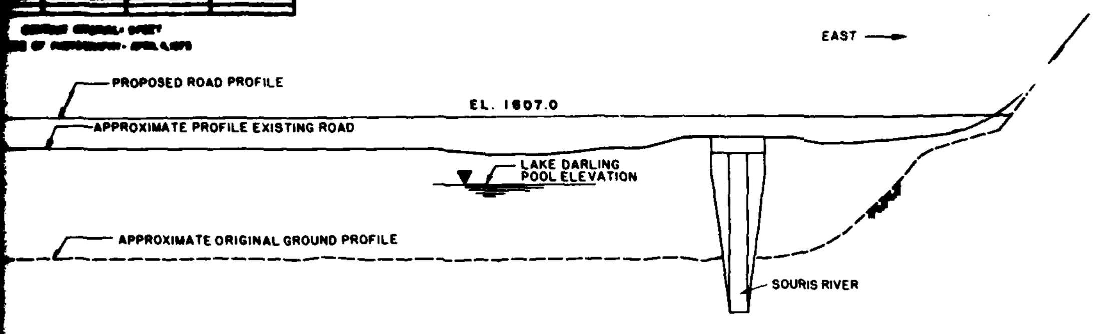
PLATE NO 9



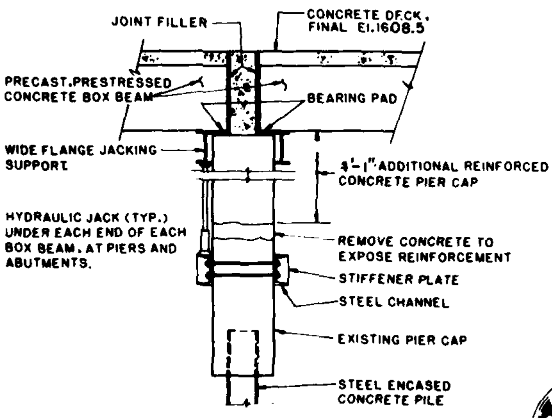
LAKE DARLING
1610.48
1609.5
1625
1603.5
1600
1602.28
1599.5
1603.5
1650
1602.20
PLAN
PROPOSED ROAD PROFILE
APPROXIMATE PROFILE EXISTING ROAD
APPROXIMATE ORIGINAL GROUND PROFILE
WEST
1620
1610
1600
ELEVATION, FEET
GUARD RAIL
40'-0"
24'-0"
8'-0"
2%
2%
GUARD RAIL
2" BITUMINOUS PAVEMENT WITH 6" BASE AND 6" SUBBASE COURSES
12" BEDDING
21" RIPRAP
EL 1607.0
21" RIPRAP
9" BEDDING
CONSERVATION POOL
EL 1597.0
RANDOM OR EXISTING FILL
18" BEDDING
27" RIPRAP
12" BEDDING
24" RIPRAP
GRANO CROSSING
TYPICAL EMBANKMENT SECTION
SCALE IN FEET
PROFILE
GRANO CROSSING BRIDGE RAISE
SCALE 0 100 500 1000 FEET
60'-0"
60'-0"
60'-0"
PROPOSED ROAD
EL.1608.5
EXISTING ROAD EL.1604.+
2.5
1
DETAIL A
PROPOSED LOW CHORD EL. 1605.5
21" RIPRAP
12" BEDDING
BACKFILL
ORIGINAL GROUND LINE
STEEL ENCASED CONCRETE PILES
STEEL ENCASED CONCRETE PILES
BACKFILL
ELEVATION
GRANO CROSSING BRIDGE RAISE
NOT TO SCALE
JOINT
PRECAST, PRESTRESSED CONCRETE BOX BEAM
WIDE FLANGE JACKING SUPPORT
HYDRAULIC JACK (TYP.) UNDER EACH END OF BOX BEAM, AT PIERS AND ABUTMENTS.
GRA



PLAN



OFILE
BRIDGE RAISE
1000 FEET



DETAIL A
GRANO CROSSING BRIDGE RAISE
NOT TO SCALE

STEPS FOR RAISE OF GRANO CROSSING BRIDGE:

1. FASTEN CHANNELS TO BOTH SIDES OF EACH PIER AND AT ABUTMENTS.
2. PLACE JACK AND W SECTION.
3. BEGIN RAISING BRIDGE BY JACKING. INTERMEDIATE LIFTS WILL BE NECESSARY.
4. ONCE DECK IS RAISED TO PROPER ELEVATION CONSTRUCT FORMS AT PIERS AND ABUTMENTS AND PLACE CONCRETE.

SAFETY PAYS

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

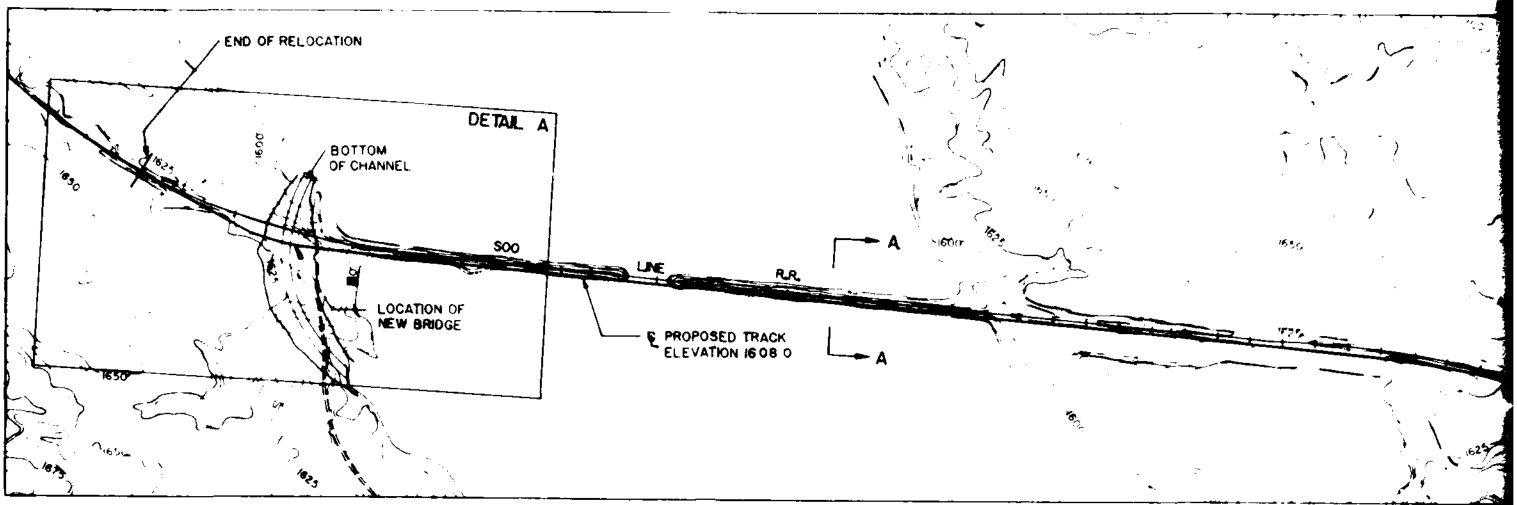
DESIGNED BY B.J.B.
DRAWN BY J.M.J.
CHECKED BY G.R.S.
SUBMITTED BY
APPROVED

DESIGN MEMORANDUM NO. 1 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
GRANO CROSSING
RELOCATION

DATE JUNE 1983
SCALE AS SHOWN
DRAWING NUMBER RI-R-5/640
SHEET OF

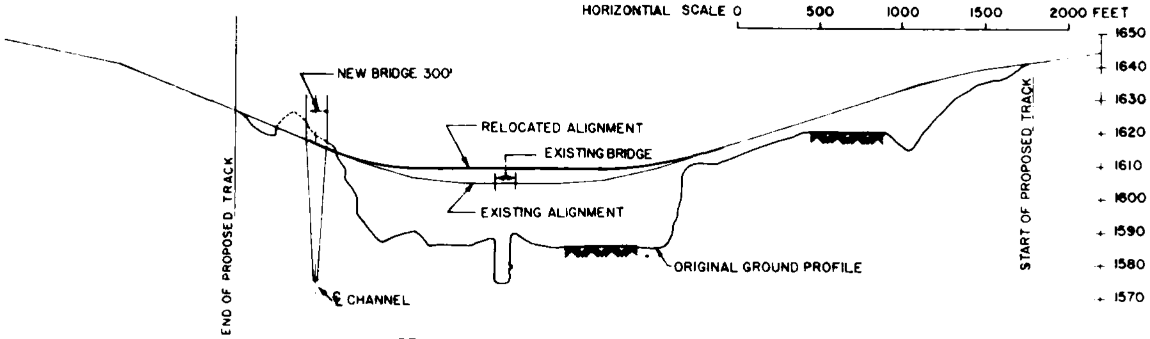
PLATE NO 10

1 2



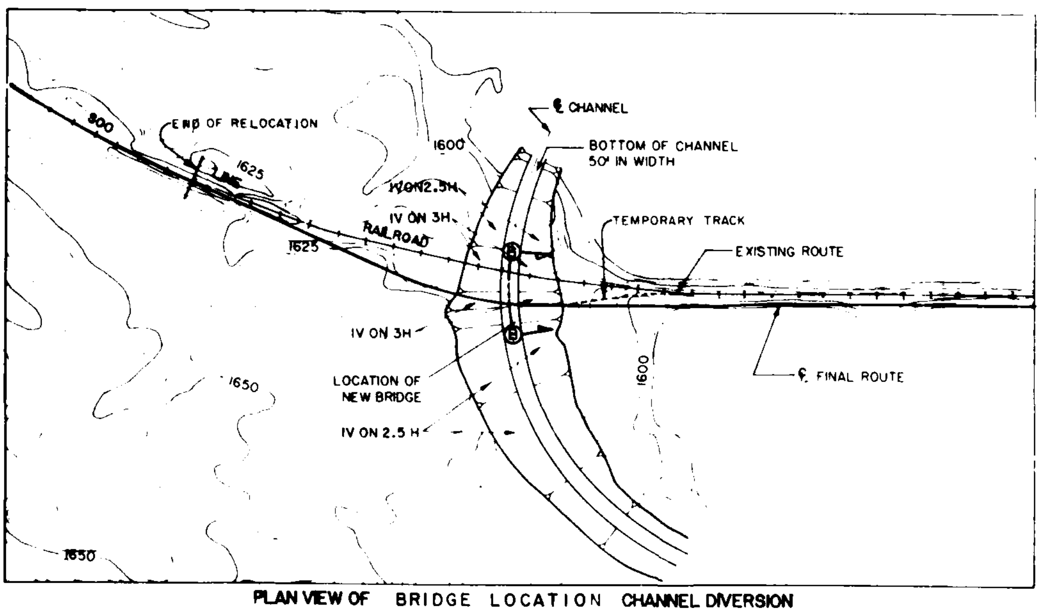
PLAN VIEW OF RELOCATION

HORIZONTIAL SCALE 0 500 1000 1500 2000 FEET



PROFILE VIEW OF RELOCATION

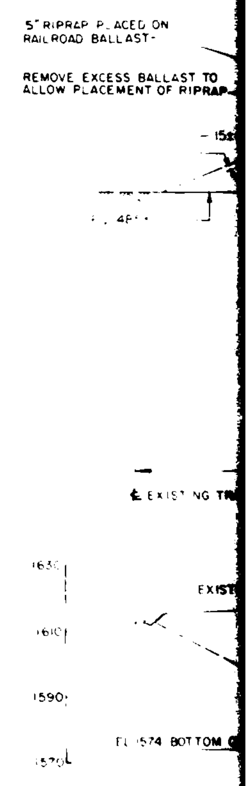
SCALE 0 1000 2000 3000 4000 FEET

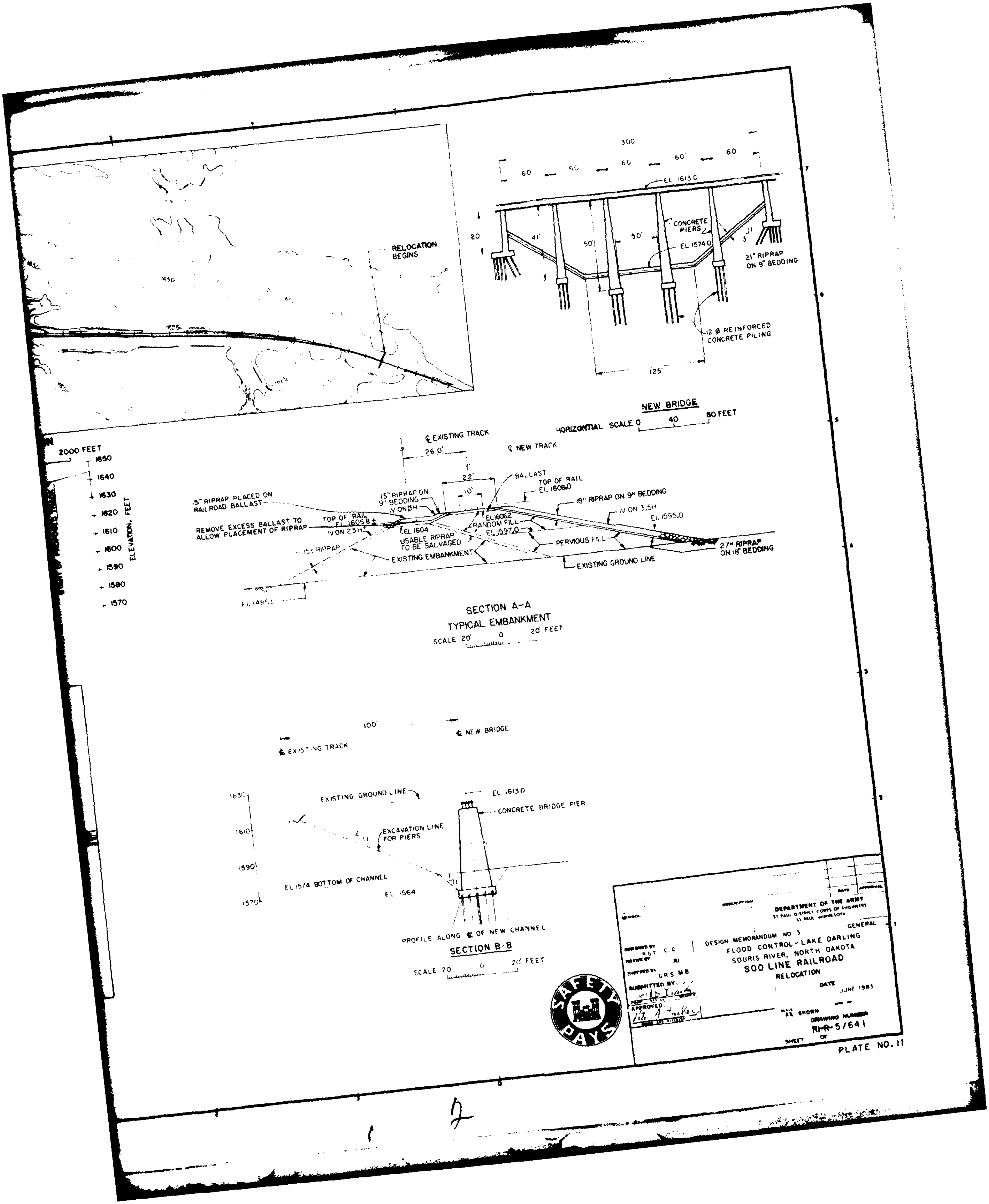


PLAN VIEW OF BRIDGE LOCATION CHANNEL DIVERSION

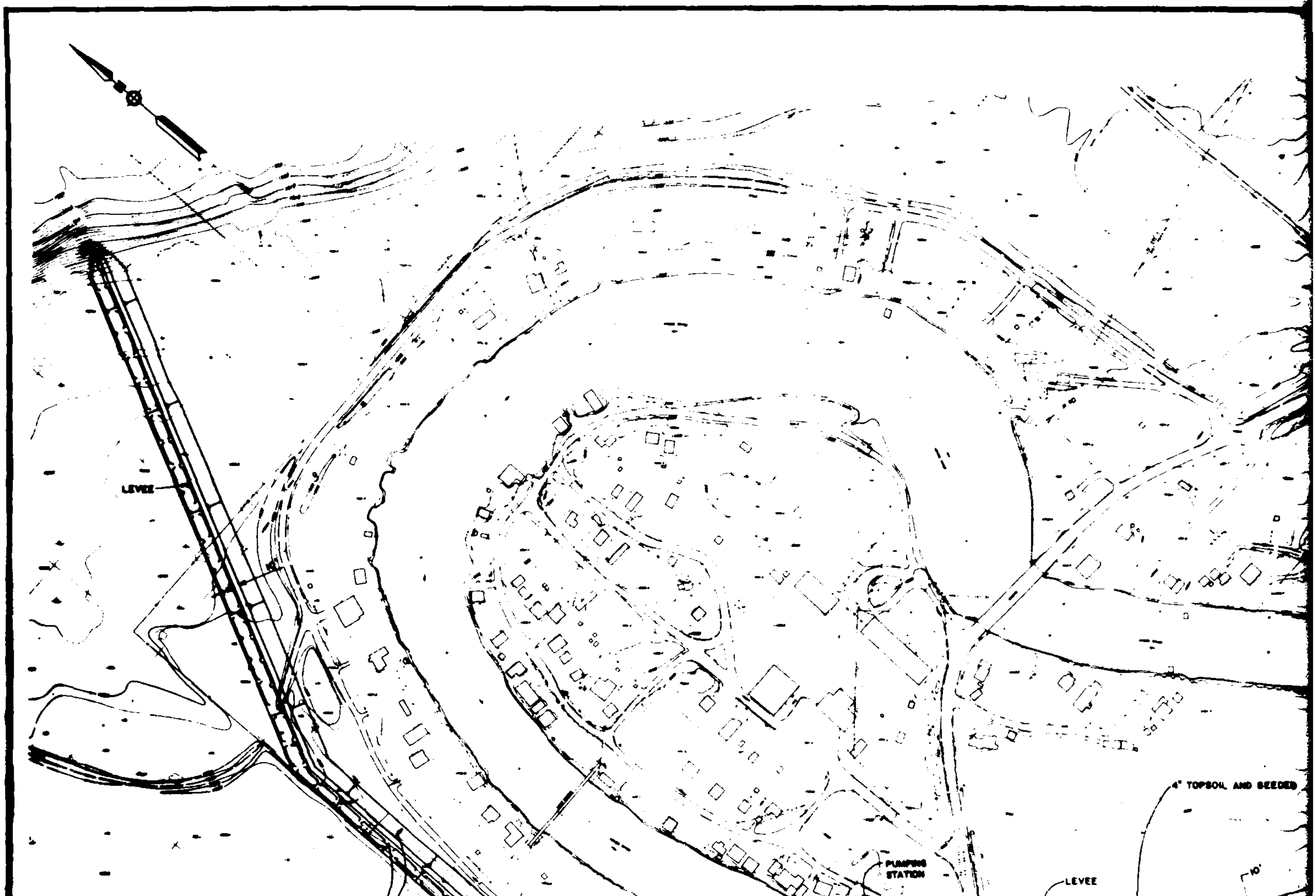
DETAIL A

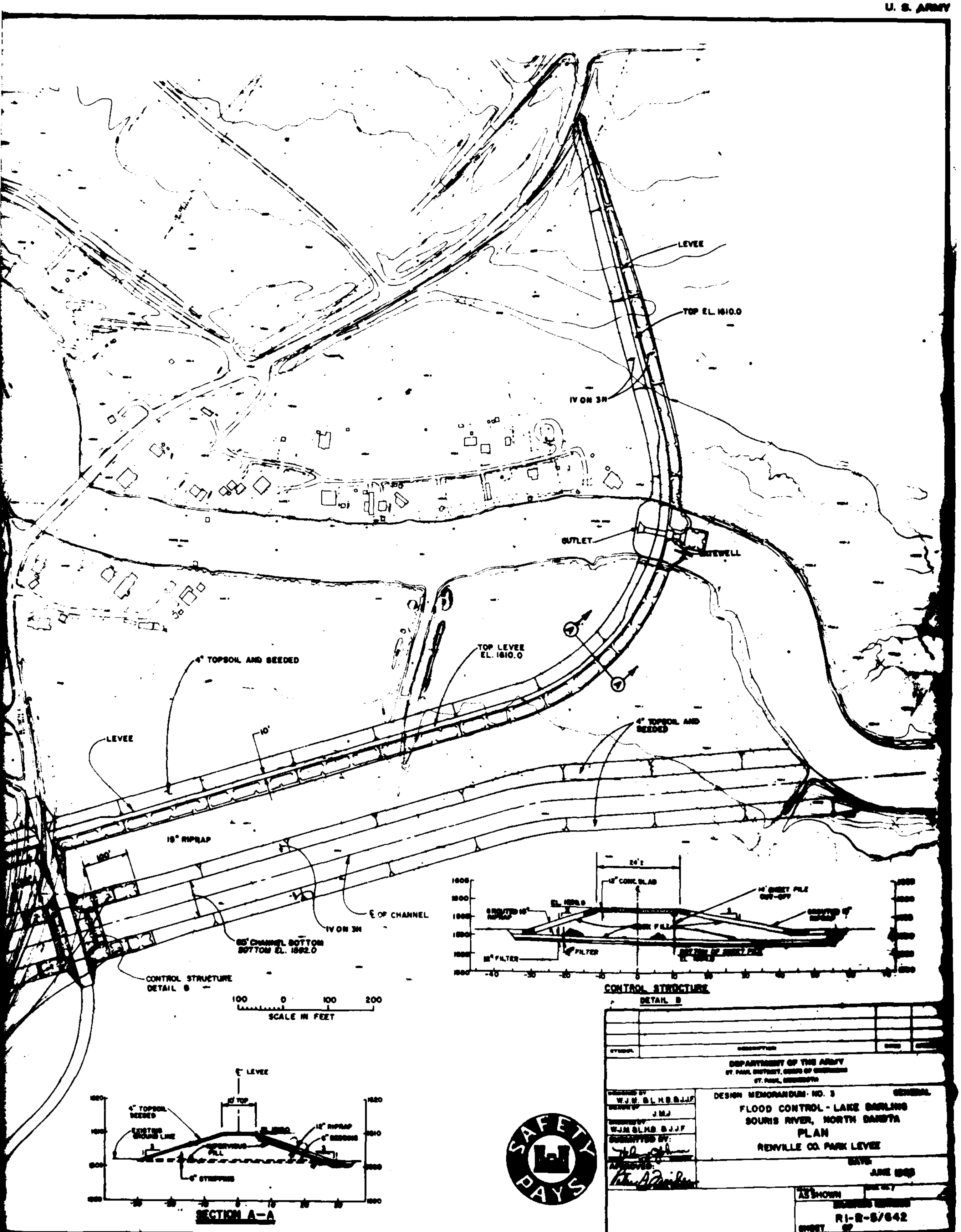
SCALE 0 100 300 500 FEET



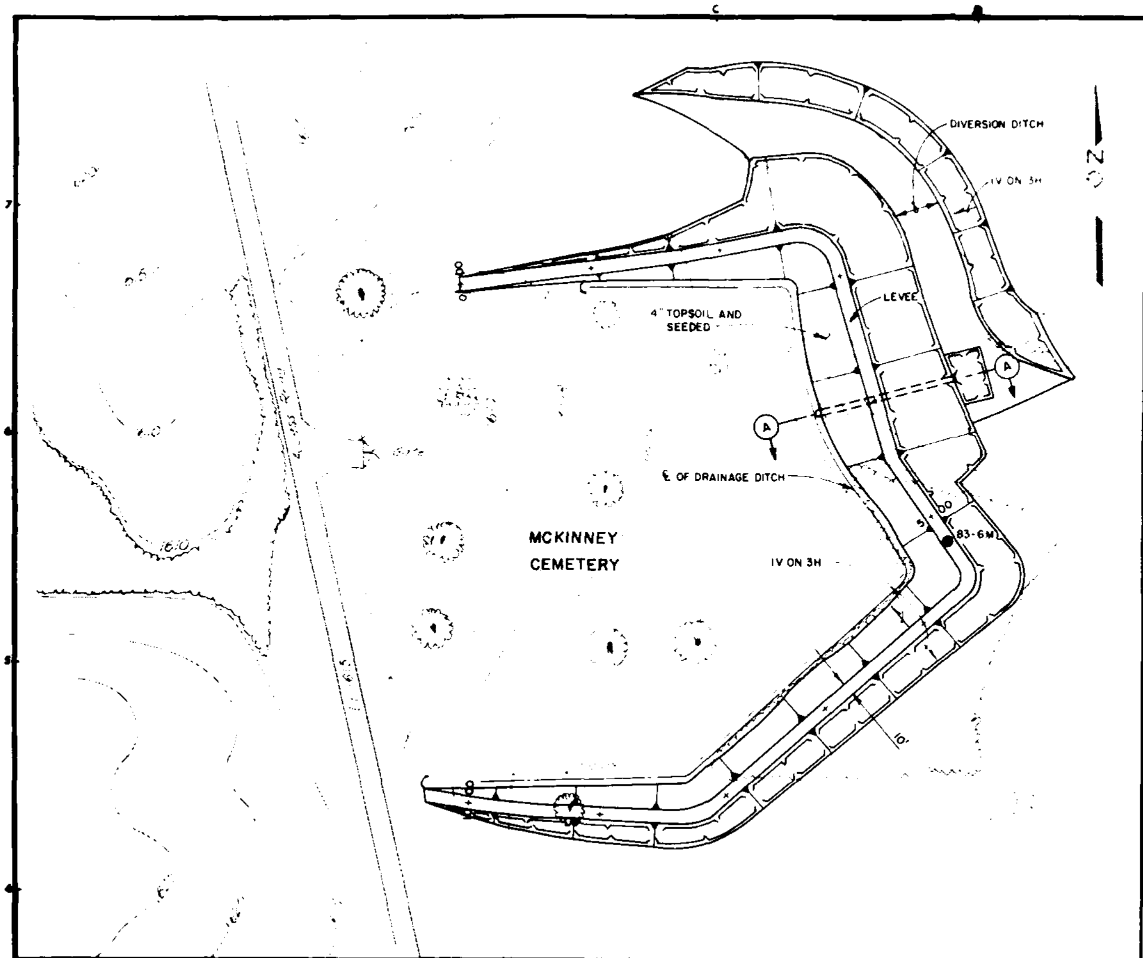

RELOCATION BEGINS
2000 FEET
ELEVATION, FEET
300
60
EL 1613.0
CONCRETE PIERS
20
41'
50'
EL 1574.0
21" RIPRAP ON 9" BEDDING
12 Ø REINFORCED CONCRETE PILING
125'
NEW BRIDGE
HORIZONTAL SCALE 0 40 80 FEET
℄ EXISTING TRACK
℄ NEW TRACK
26.0'
22'
10'
BALLAST
TOP OF RAIL EL 1608.0
15" RIPRAP PLACED ON RAILROAD BALLAST
15" RIPRAP ON 9" BEDDING
1V ON 3H
18" RIPRAP ON 9" BEDDING
1V ON 3.5H
EL 1595.0
REMOVE EXCESS BALLAST TO ALLOW PLACEMENT OF RIPRAP
TOP OF RAIL EL 1605.8
1V ON 2.5H
EL 1604
EL 1606.2
RANDOM FILL
EL 1597.0
USABLE RIPRAP TO BE SALVAGED
PERVIOUS FILL
27" RIPRAP ON 18" BEDDING
EXISTING EMBANKMENT
EXISTING GROUND LINE
SECTION A-A
TYPICAL EMBANKMENT
SCALE 20' 0 20' FEET
100
℄ NEW BRIDGE
℄ EXISTING TRACK
EXISTING GROUND LINE
EL 1613.0
CONCRETE BRIDGE PIER
EXCAVATION LINE FOR PIERS
EL 1574 BOTTOM OF CHANNEL
EL 1564
PROFILE ALONG ℄ OF NEW CHANNEL
SECTION B-B
SCALE 20' 0 20' FEET
SAFETY PAYS
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA
GENERAL
DESIGN MEMORANDUM NO. 3
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
SOO LINE RAILROAD
RELOCATION
DATE JUNE 1983
AS SHOWN
DRAWING NUMBER
RI-R-5/641
PLATE NO. 11

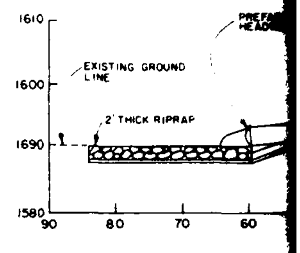
CORPS OF ENGINEERS




LEVEE
TOP EL. 1610.0
IV ON 3H
OUTLET
GATEWELL
TOP LEVEE EL. 1610.0
4" TOPSOIL AND SEEDED
LEVEE
10'
4" TOPSOIL AND SEEDED
18" RIPRAP
100'
℄ OF CHANNEL
IV ON 3H
60' CHANNEL BOTTOM
BOTTOM EL. 1582.0
CONTROL STRUCTURE
DETAIL B
100 0 100 200
SCALE IN FEET
CONTROL STRUCTURE
DETAIL B
℄ LEVEE
10' TOP
4" TOPSOIL SEEDED
EXISTING GROUND LINE
IMPERVIOUS FILL
12" RIPRAP
6" BEDDING
6" STRIPPING
SECTION A-A
SAFETY PAYS
DEPARTMENT OF THE ARMY
DESIGN MEMORANDUM NO. 3
GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
PLAN
RENVILLE CO. PARK LEVEE
JUNE 1969
AS SHOWN
RI-R-S/642

2

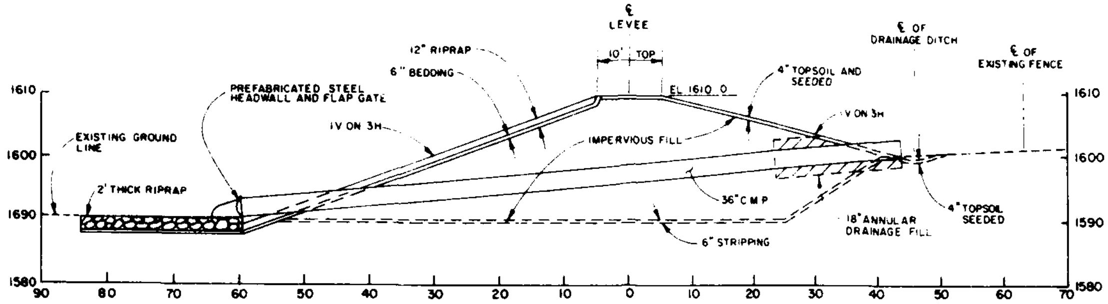




PLAN

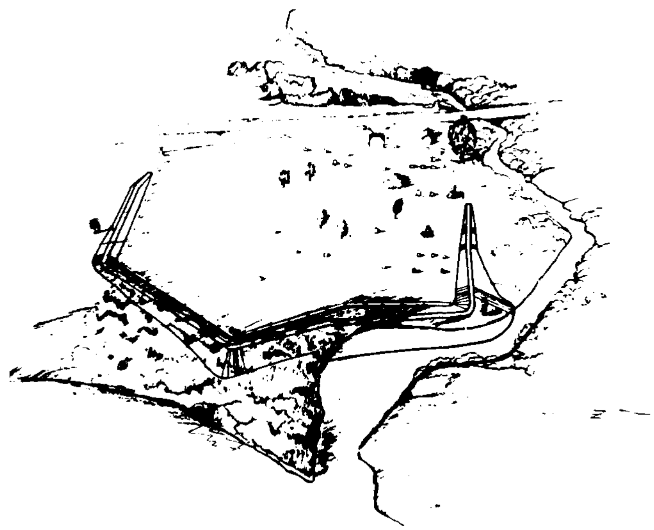
0 50 100

SCALE IN FEET



SECTION A-A

STATION 4+00



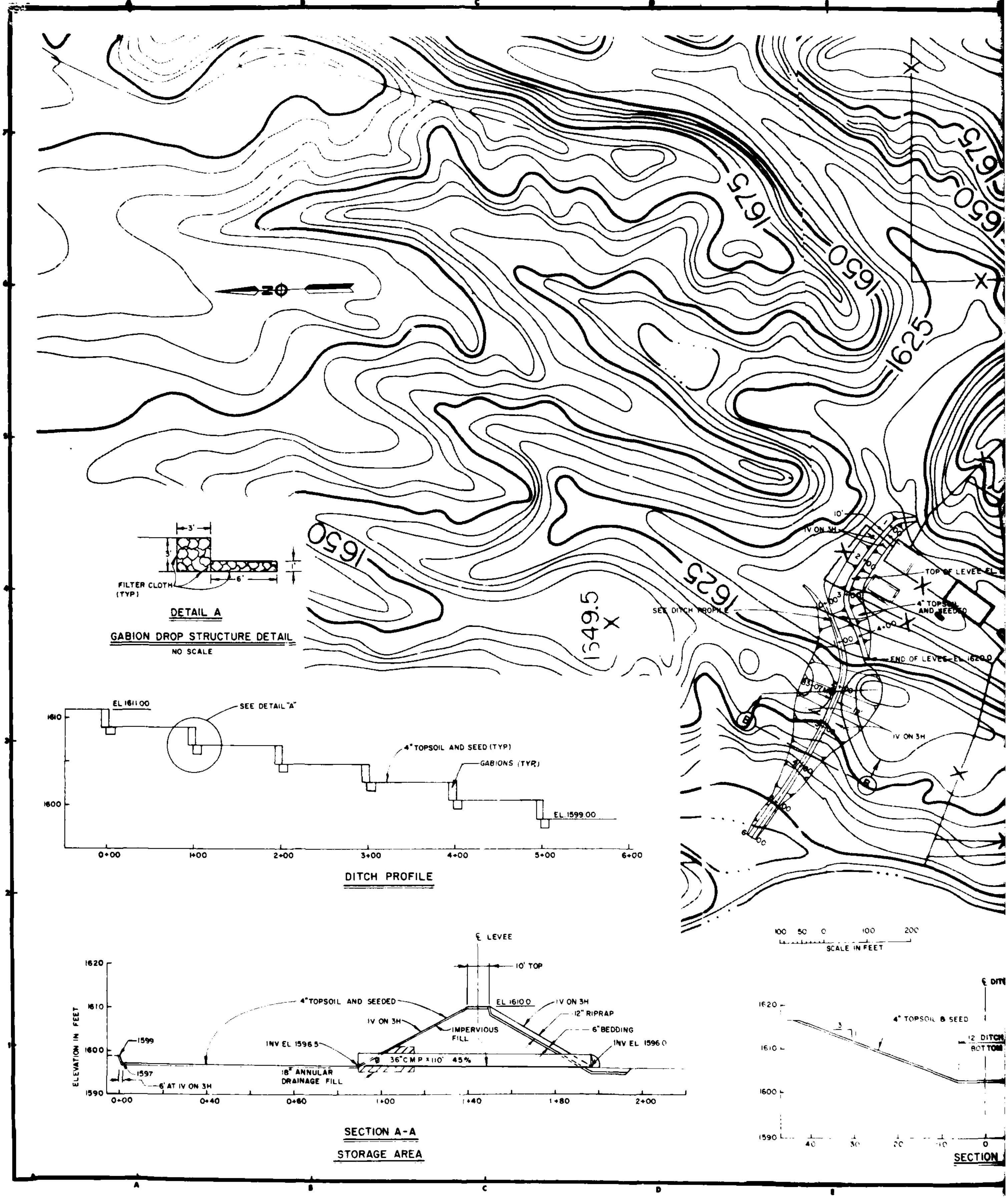
SCHEMATIC

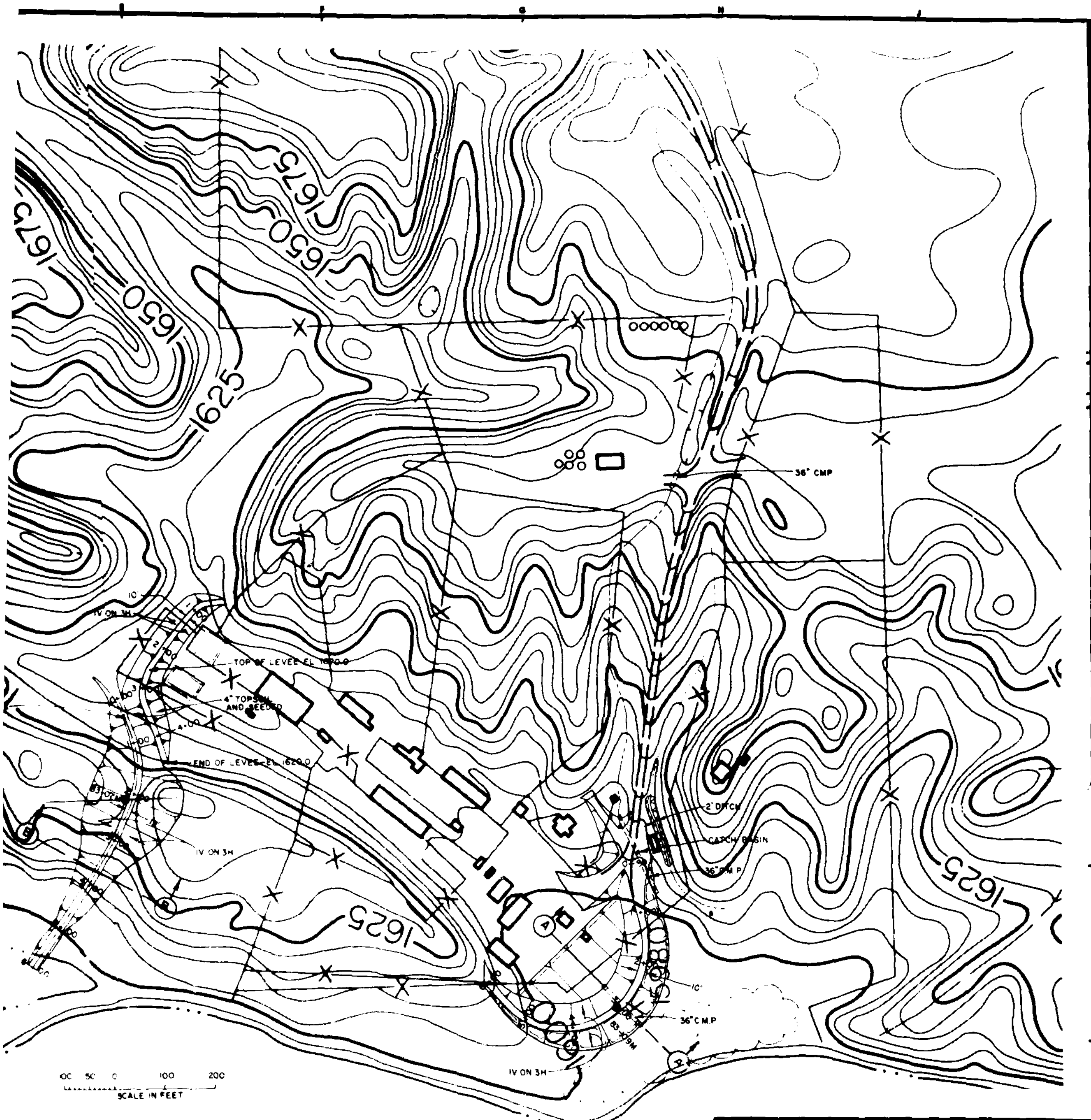
SYMBOL	DESCRIPTION	DATE	APPROVAL

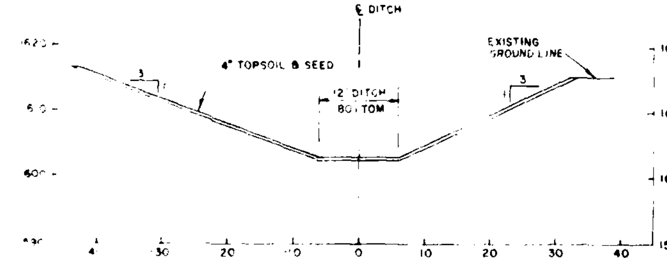
DEPARTMENT OF THE ARMY
ST PAUL DISTRICT CORPS OF ENGINEERS
ST PAUL MINNESOTA

DESIGNED BY: W.J.M. L.H.B. J.J.F.	DESIGN MEMORANDUM NO 3 GENERAL
DRAWN BY: DNE	FLOOD CONTROL - LAKE DARLING
CHECKED BY: W.J.M. L.H.B. J.J.F.	SOURIS RIVER, NORTH DAKOTA
SUBMITTED BY:	PLAN AND SECTIONS
	MCKINNEY CEMETERY LEVEE
APPROVED:	DATE: JUNE 1963
	SCALE: AS SHOWN
	DRAWING NUMBER: RI-R-5/643
	SHEET OF

PLATE NO. 13


1675
1650
1625
1649.5
10'
1V ON 3H
TOP OF LEVEE EL
4" TOPSOIL AND SEEDED
SEE DITCH PROFILE
END OF LEVEE EL 1620.0
1V ON 3H
3'
6'
FILTER CLOTH (TYP)
DETAIL A
GABION DROP STRUCTURE DETAIL
NO SCALE
EL 1611.00
SEE DETAIL "A"
4" TOPSOIL AND SEED (TYP)
GABIONS (TYP)
EL 1599.00
1610
1600
0+00
1+00
2+00
3+00
4+00
5+00
6+00
DITCH PROFILE
100 50 0 100 200
SCALE IN FEET
℄ LEVEE
10' TOP
4" TOPSOIL AND SEEDED
EL 1610.0
1V ON 3H
12" RIPRAP
6" BEDDING
IMPERVIOUS FILL
INV EL 1596.5
INV EL 1596.0
36" CMP x 110' 45%
18" ANNULAR DRAINAGE FILL
1599
1597
6' AT 1V ON 3H
ELEVATION IN FEET
1620
1610
1600
1590
0+00
0+40
0+80
1+00
1+40
1+80
2+00
SECTION A-A
STORAGE AREA
4" TOPSOIL & SEED
12" DITCH BOTTOM
40
30
20
10
0
SECTION





SECTION B-B

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: W J M & L H B & J J F
DRAWN BY: J M J
CHECKED BY: W J M & M M B & A M K
SUBMITTED BY:
APPROVED:

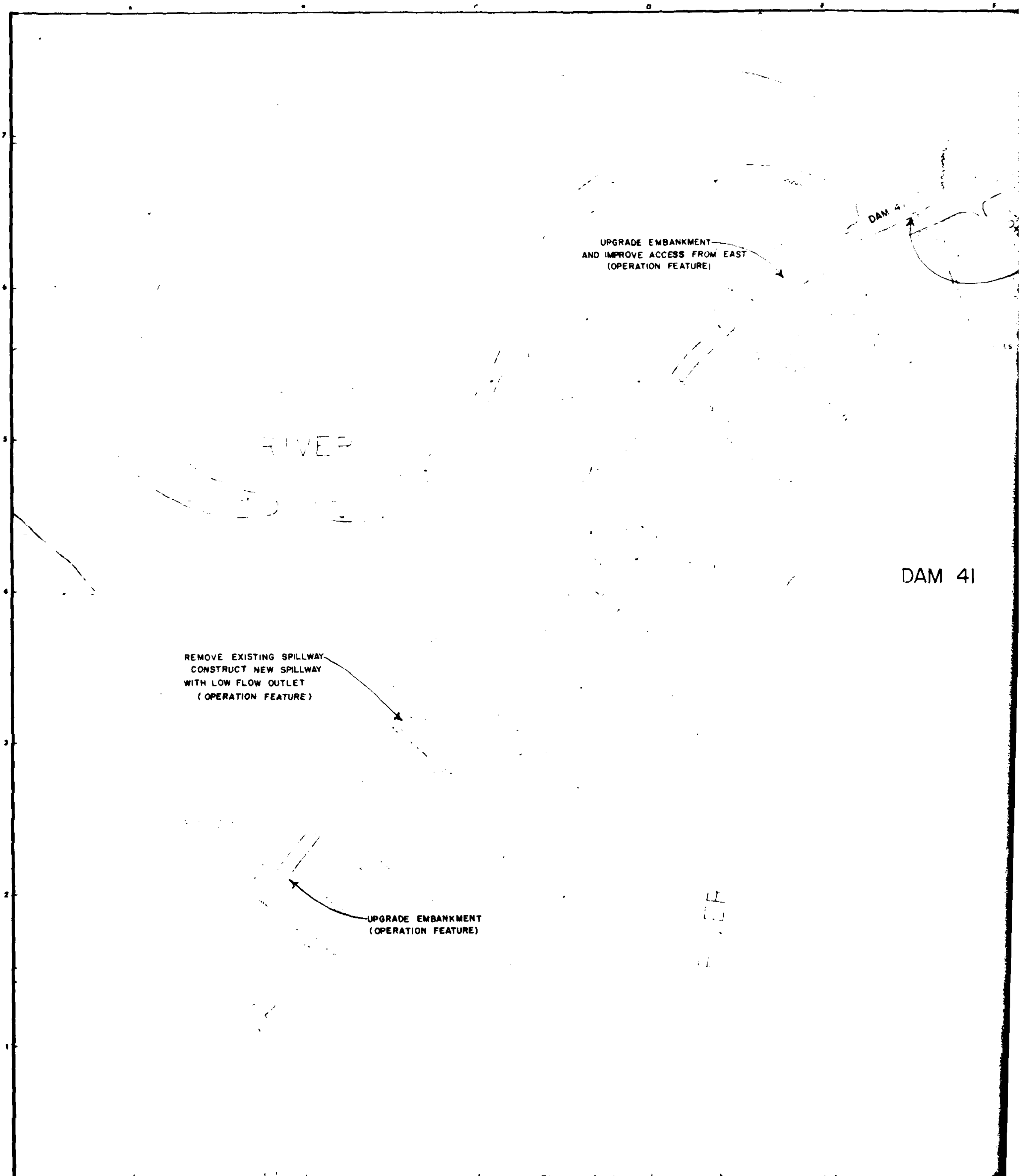
DESIGN MEMORANDUM NO 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
PLAN
ECKERT RANCH

DATE: JUNE 1983

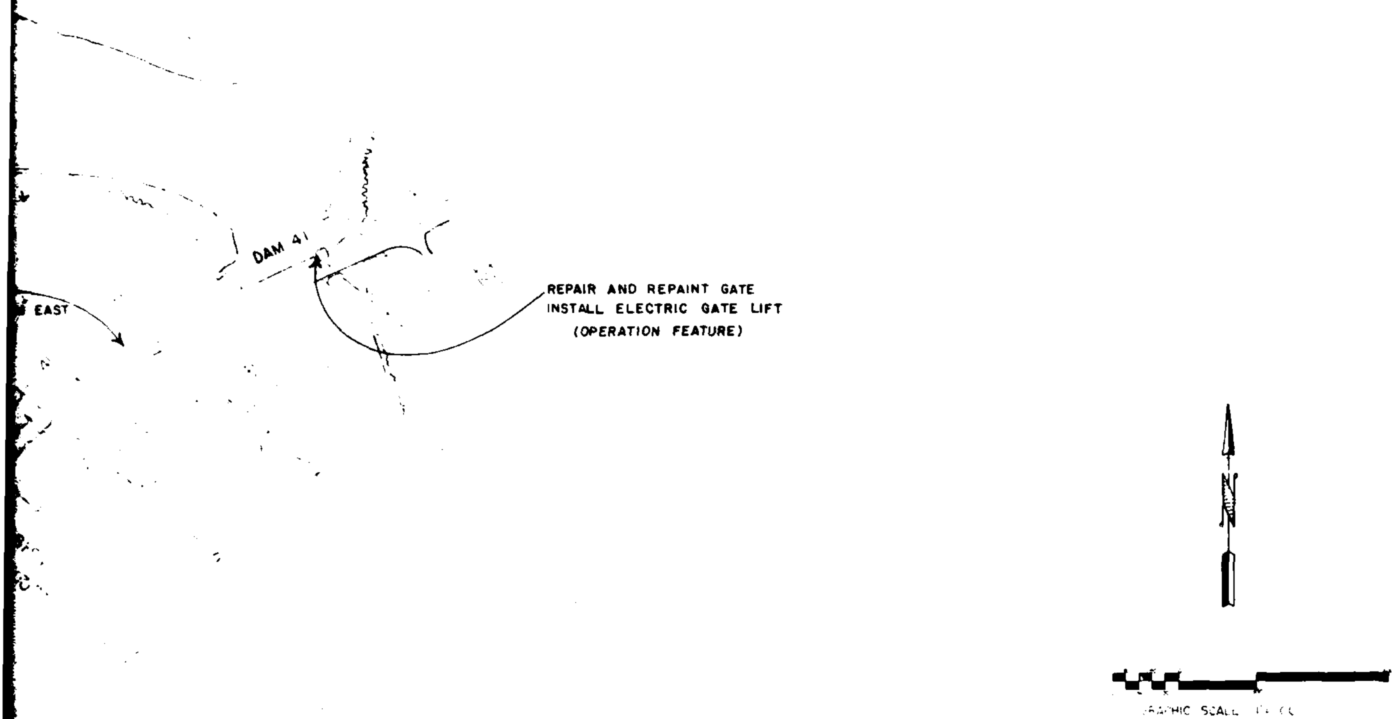
DRAWING NUMBER
R1-R-5/644

PLATE NO.14

1 2



UPGRADE EMBANKMENT AND IMPROVE ACCESS FROM EAST (OPERATION FEATURE)
DAM 41
REMOVE EXISTING SPILLWAY CONSTRUCT NEW SPILLWAY WITH LOW FLOW OUTLET (OPERATION FEATURE)
UPGRADE EMBANKMENT (OPERATION FEATURE)
DAM 41



DAM 41

LEGEND

WATER
CONTROL STRUCTURE
MARSH AREAS
WOODED AREAS

POINT COORDINATES

NOTES:

1 SEE PLATE NO. 19 UPPER SOURIS REFUGE-TYPICAL STRUCTURES

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

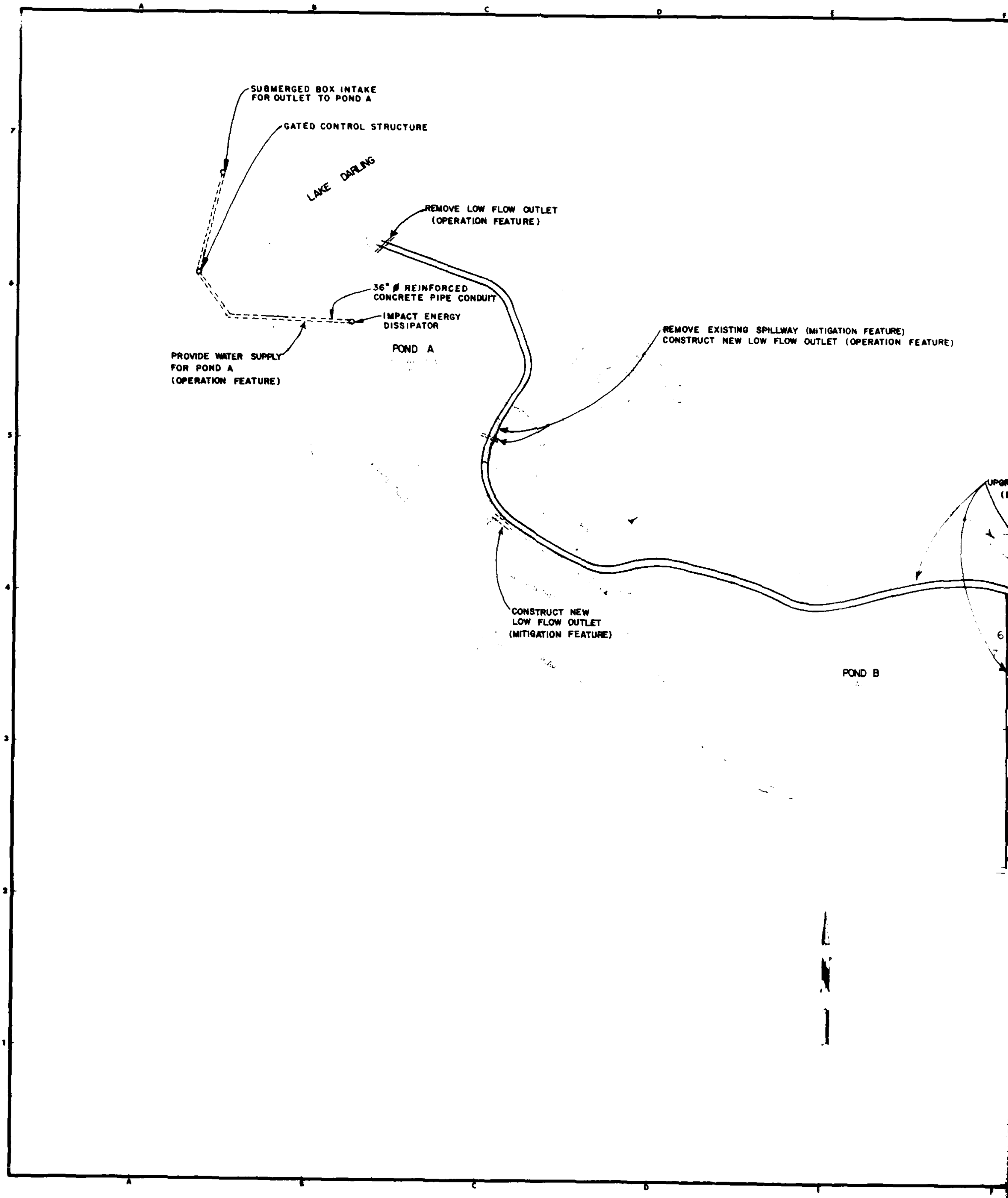
DESIGNED BY: B.J.B.
DRAWN BY: J.R.J.
CHECKED BY: G.R.S.
SUBMITTED BY:
APPROVED:

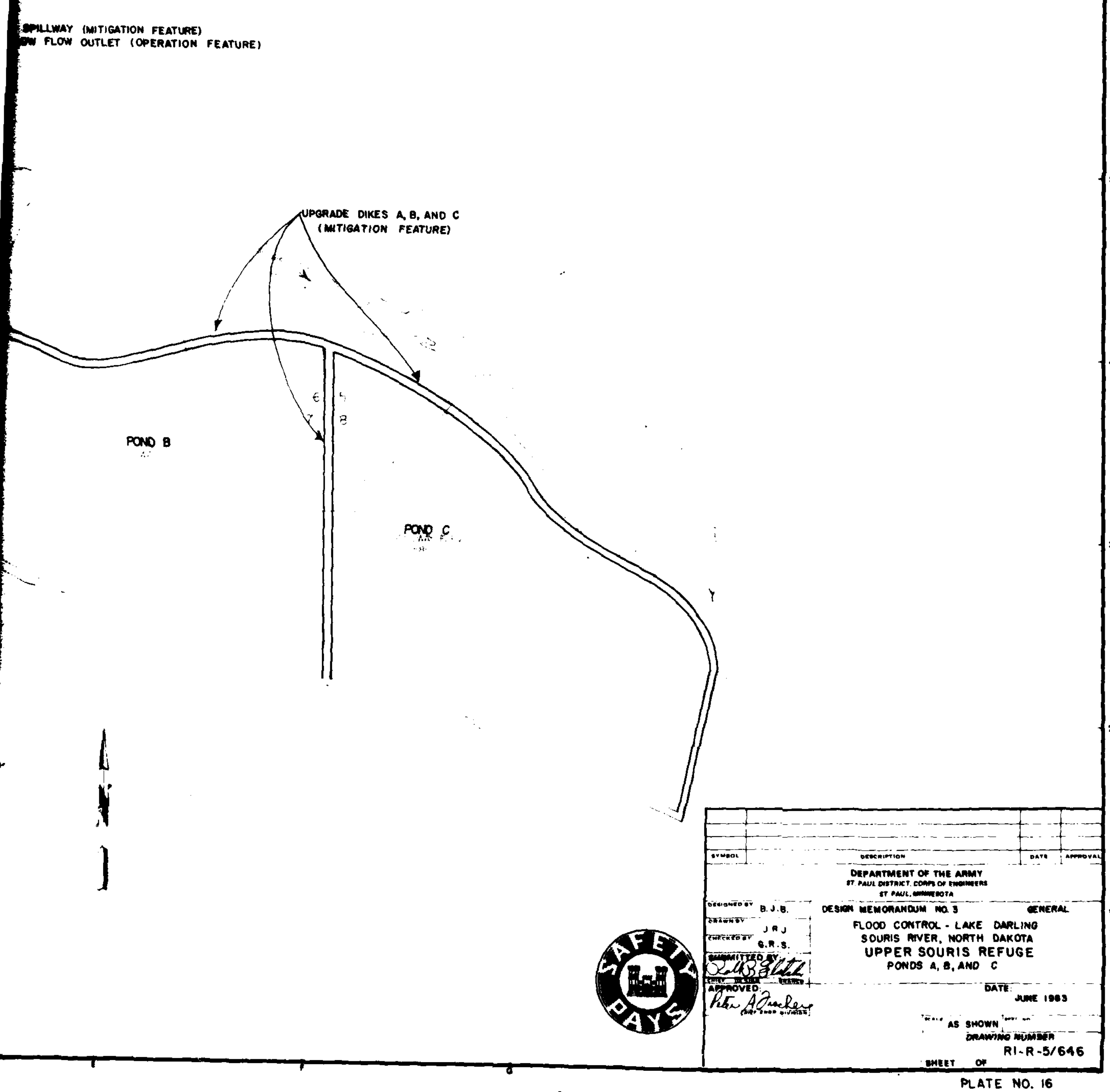
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
UPPER SOURIS REFUGE
DAM 41

DATE: JUNE 1983
SCALE: AS SHOWN
DRAWING NUMBER: RI-R-5/645
SHEET OF

PLATE NO. 15

1 2


SUBMERGED BOX INTAKE
FOR OUTLET TO POND A
GATED CONTROL STRUCTURE
LAKE DARLING
REMOVE LOW FLOW OUTLET
(OPERATION FEATURE)
36" ∅ REINFORCED
CONCRETE PIPE CONDUIT
IMPACT ENERGY
DISSIPATOR
POND A
PROVIDE WATER SUPPLY
FOR POND A
(OPERATION FEATURE)
REMOVE EXISTING SPILLWAY (MITIGATION FEATURE)
CONSTRUCT NEW LOW FLOW OUTLET (OPERATION FEATURE)
CONSTRUCT NEW
LOW FLOW OUTLET
(MITIGATION FEATURE)
POND B
A
B
C
D
E
F
7
6
5
4
3
2
1



SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY B. J. B.
DRAWN BY J R J
CHECKED BY G. R. S.
SUBMITTED BY:
APPROVED:

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
UPPER SOURIS REFUGE
PONDS A, B, AND C

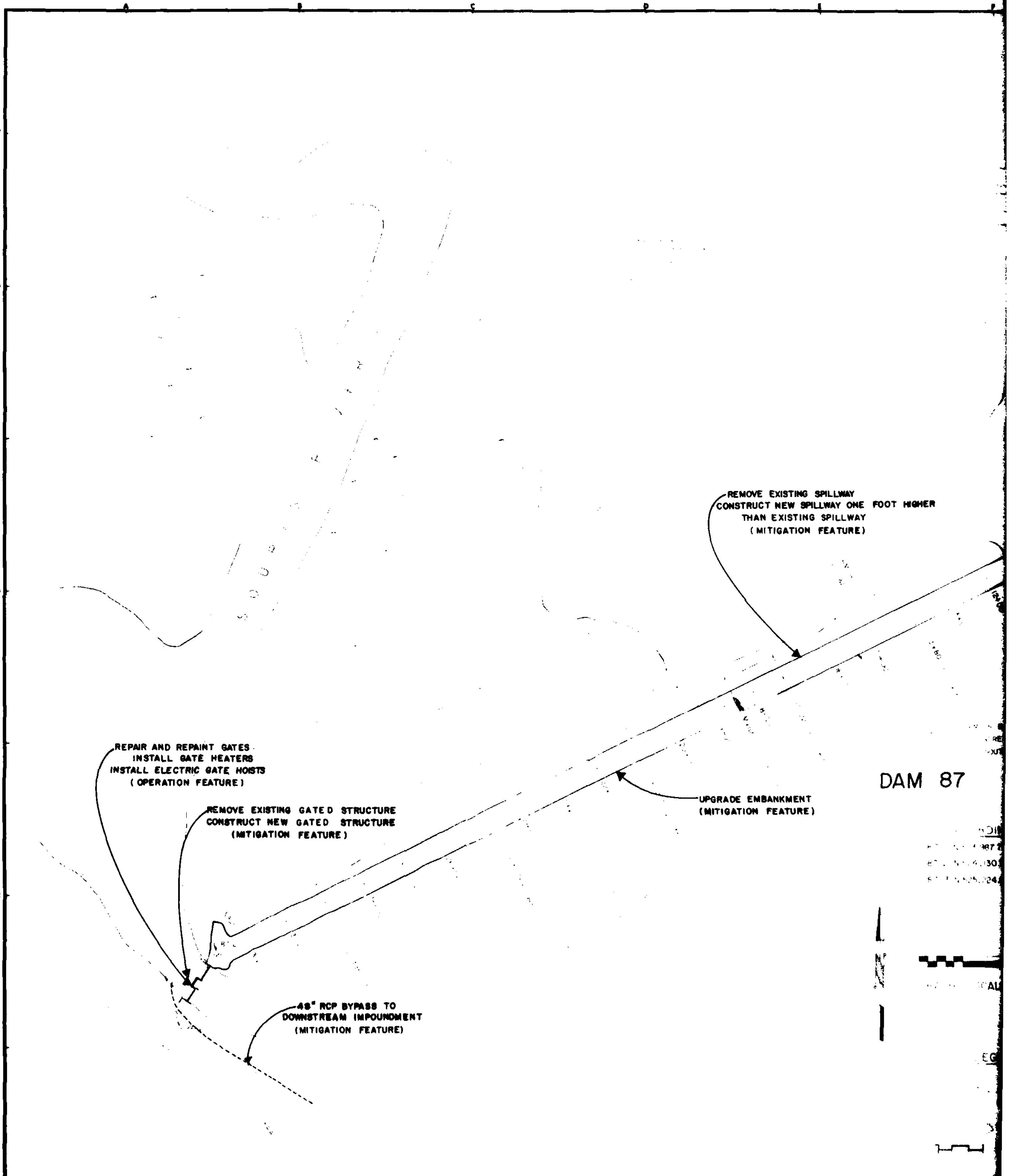
DATE: JUNE 1983

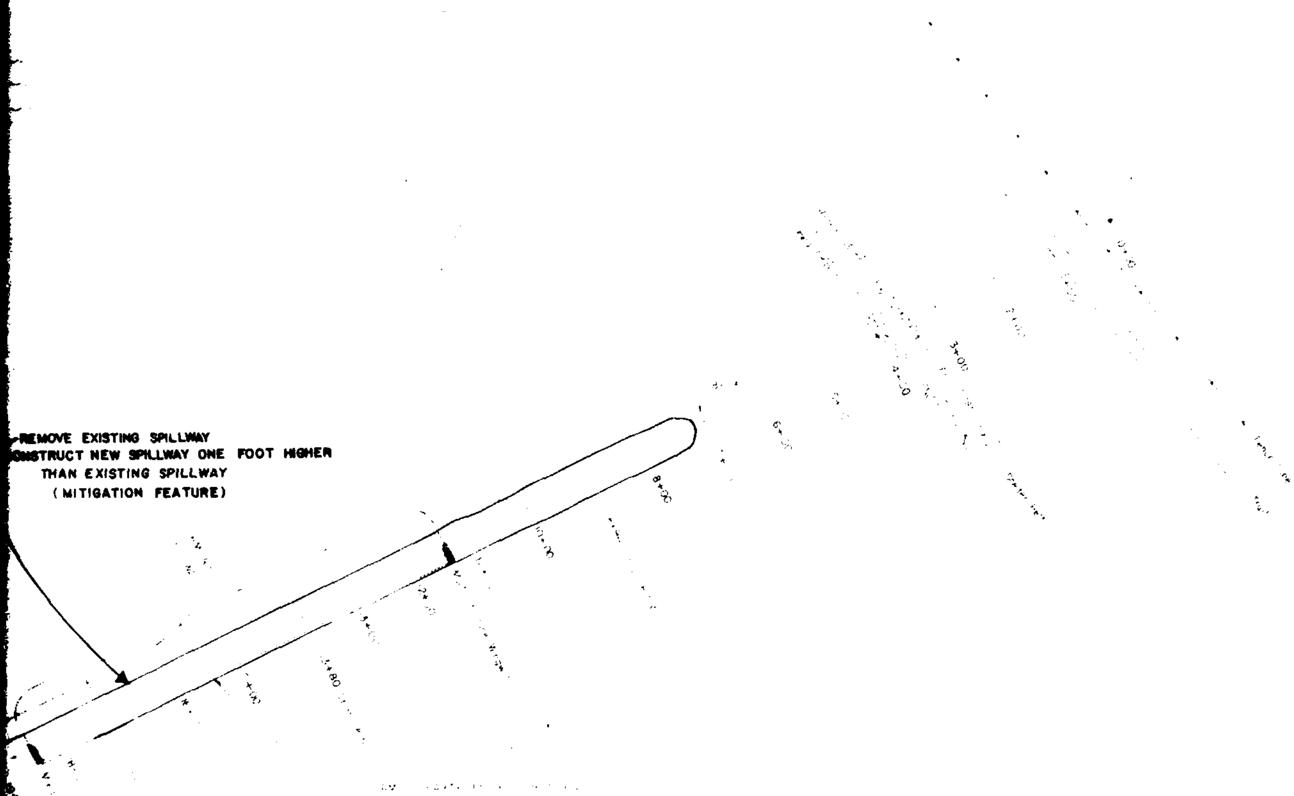
SCALE AS SHOWN

DRAWING NUMBER RI-R-5/646

SHEET OF

PLATE NO. 16

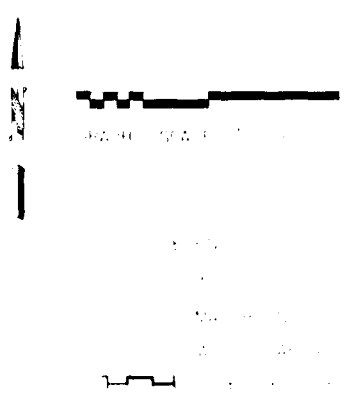

REMOVE EXISTING SPILLWAY
CONSTRUCT NEW SPILLWAY ONE FOOT HIGHER THAN EXISTING SPILLWAY
(MITIGATION FEATURE)
REPAIR AND REPAINT GATES
INSTALL GATE HEATERS
INSTALL ELECTRIC GATE HOISTS
(OPERATION FEATURE)
DAM 87
REMOVE EXISTING GATED STRUCTURE
CONSTRUCT NEW GATED STRUCTURE
(MITIGATION FEATURE)
UPGRADE EMBANKMENT
(MITIGATION FEATURE)
48" RCP BYPASS TO DOWNSTREAM IMPOUNDMENT
(MITIGATION FEATURE)



NOTES:
1. SEE PLATE NO. 19 UPPER SOURIS REFUGE-TYPICAL STRUCTURES

DAM 87

ADE EMBANKMENT
GATION FEATURE)



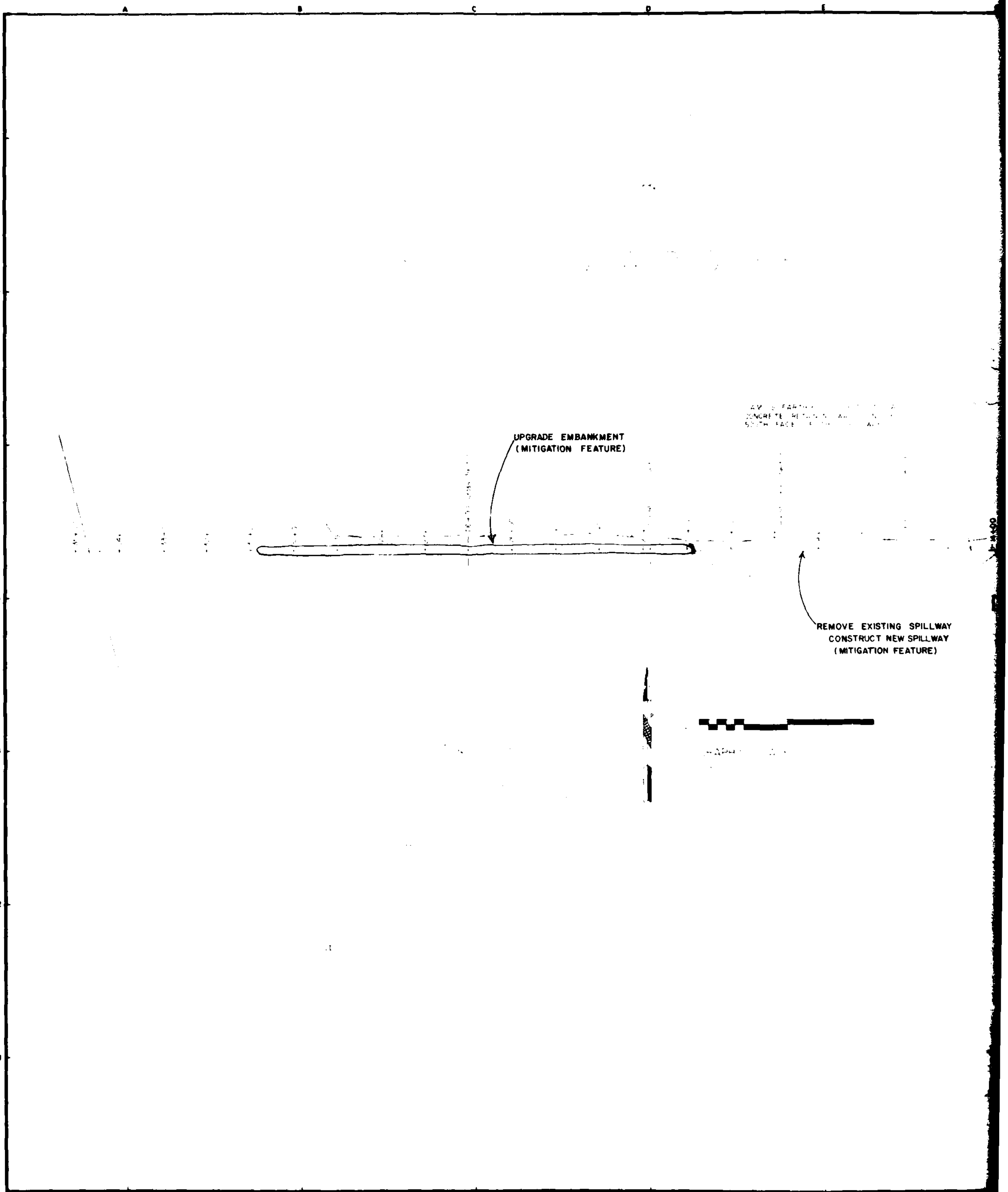
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

B.J.B.	DESIGN MEMORANDUM NO. 3 GENERAL
J.R.J.	FLOOD CONTROL - LAKE DARLING
G.R.S.	SOURIS RIVER, NORTH DAKOTA
SUBMITTED BY:	UPPER SOURIS REFUGE
APPROVED:	DAM 87
	DATE: JUNE 1983
	AS SHOWN
	DRAWING NUMBER RI-R-5/647
	SHEET OF

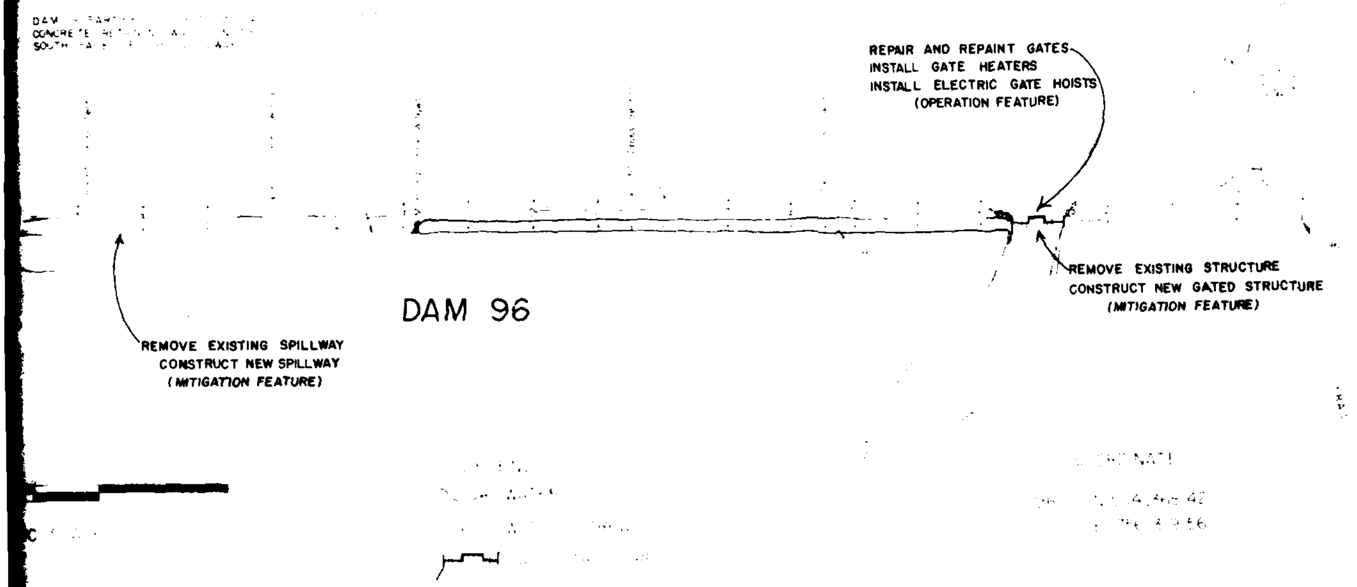
SAFETY PAYS

PLATE NO. 17

7



UPGRADE EMBANKMENT
(MITIGATION FEATURE)
REMOVE EXISTING SPILLWAY
CONSTRUCT NEW SPILLWAY
(MITIGATION FEATURE)



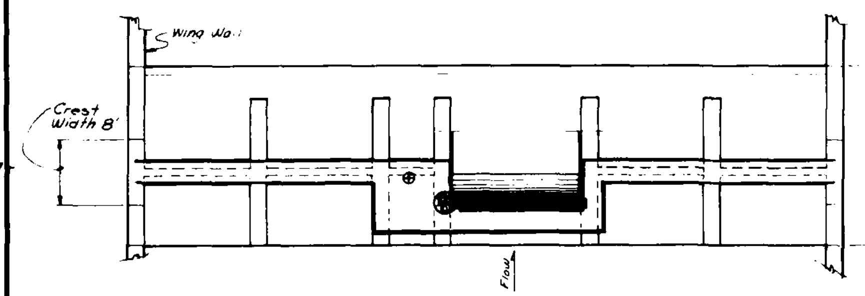
NOTES:
1. SEE PLATE NO. 19 UPPER SOURIS REFUGE-TYPICAL STRUCTURES

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
UPPER SOURIS REFUGE
DAM 96

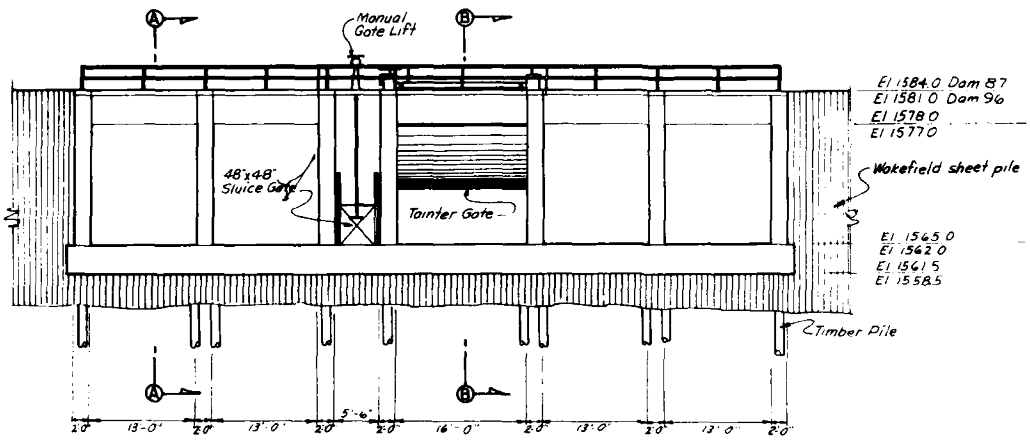
DESIGNED BY B.J.B.
DRAWN BY J.R.J.
CHECKED BY G.R.S.
SUBMITTED BY
APPROVED

DATE JUNE 1983
SCALE AS SHOWN
DRAWING NUMBER RI-R-5/648



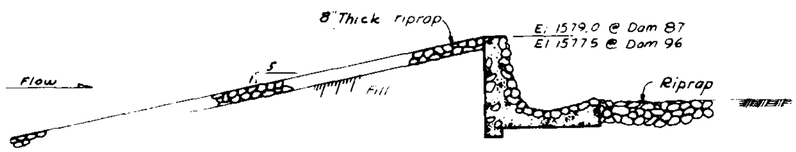
PLAN

12" 0 5'
SCALE IN FEET



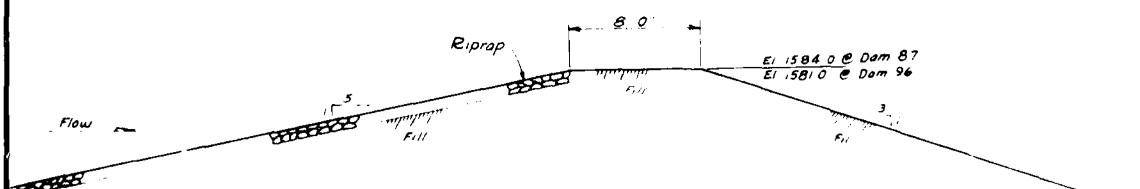
TYPICAL GATE STRUCTURE ELEVATION

12"0 5' 10' 15'
SCALE IN FEET



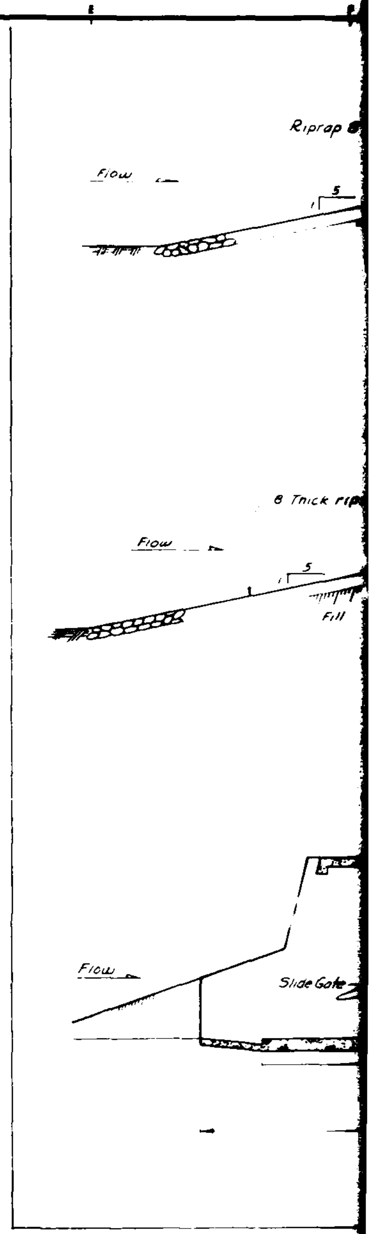
TYPICAL SPILLWAY SECTION

12" 0 5'
SCALE IN FEET

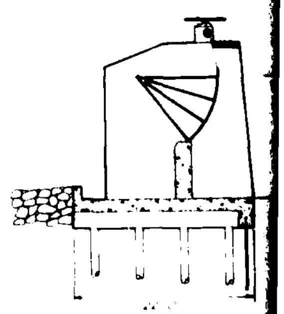


TYPICAL SECTION THRU EMBANKMENT

12" 0 5'
SCALE IN FEET

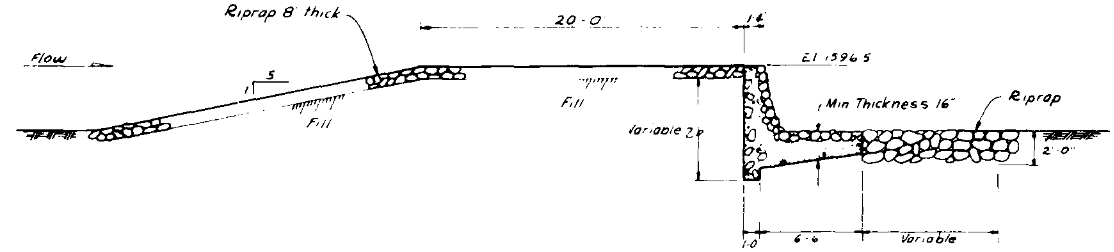


EXISTING STRUCTURES
DAMS 87 and 96



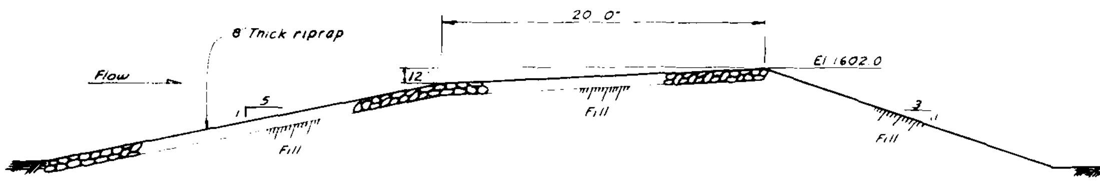
SECTION B-B

12"0 5' 10' 15'
SCALE IN FEET



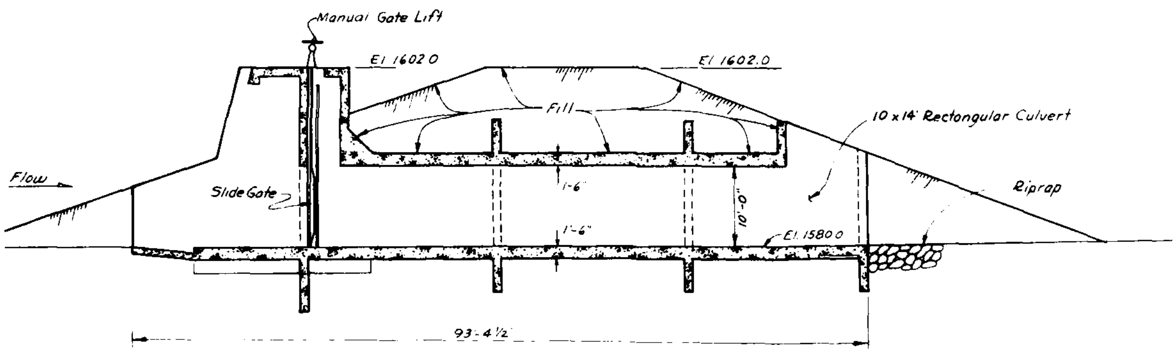
TYPICAL SECTION THRU SPILLWAY

12" 0 5' SCALE IN FEET



TYPICAL SECTION THRU EMBANKMENT

12" 0 5' SCALE IN FEET

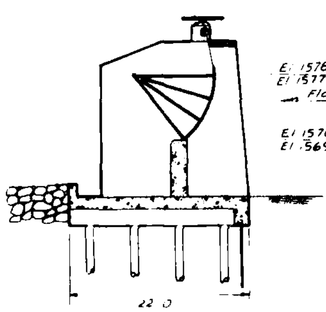


TYPICAL SECTION THRU GATE STRUCTURE

12" 0 5' 10' 15' SCALE IN FEET

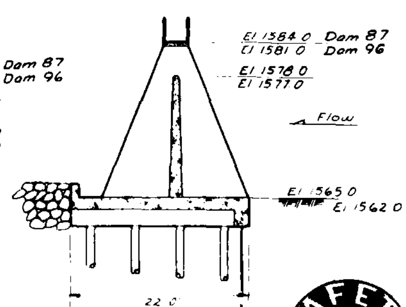
DAM 41 EXISTING STRUCTURES

Notes:
1 New spillway sections will be similar to Typical New Spillway Section as shown on Plate 24



SECTION B-B

12" 0 5' 10' 15' SCALE IN FEET



SECTION A-A

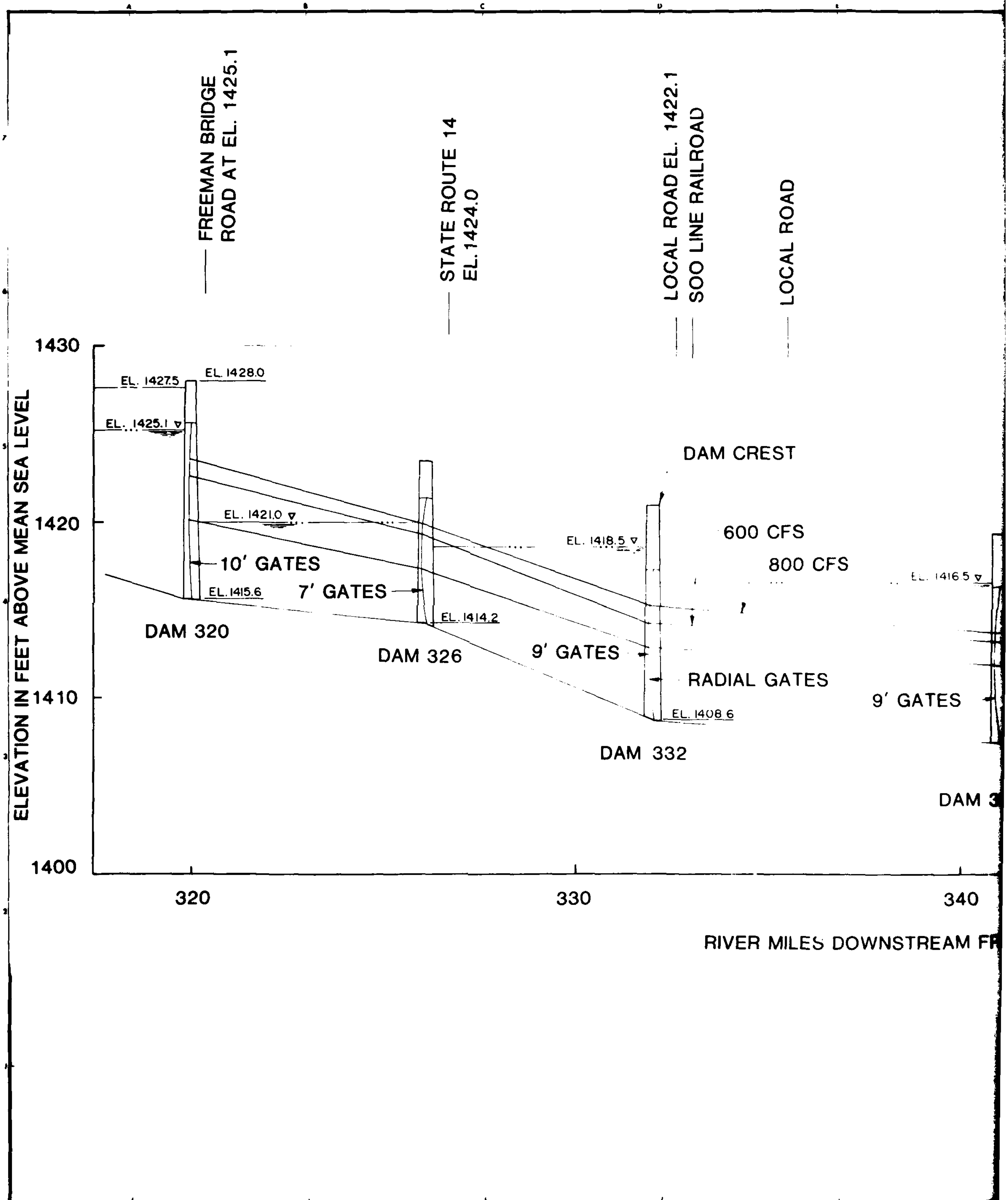
12" 0 5' 10' 15' SCALE IN FEET

SAFETY PAYS

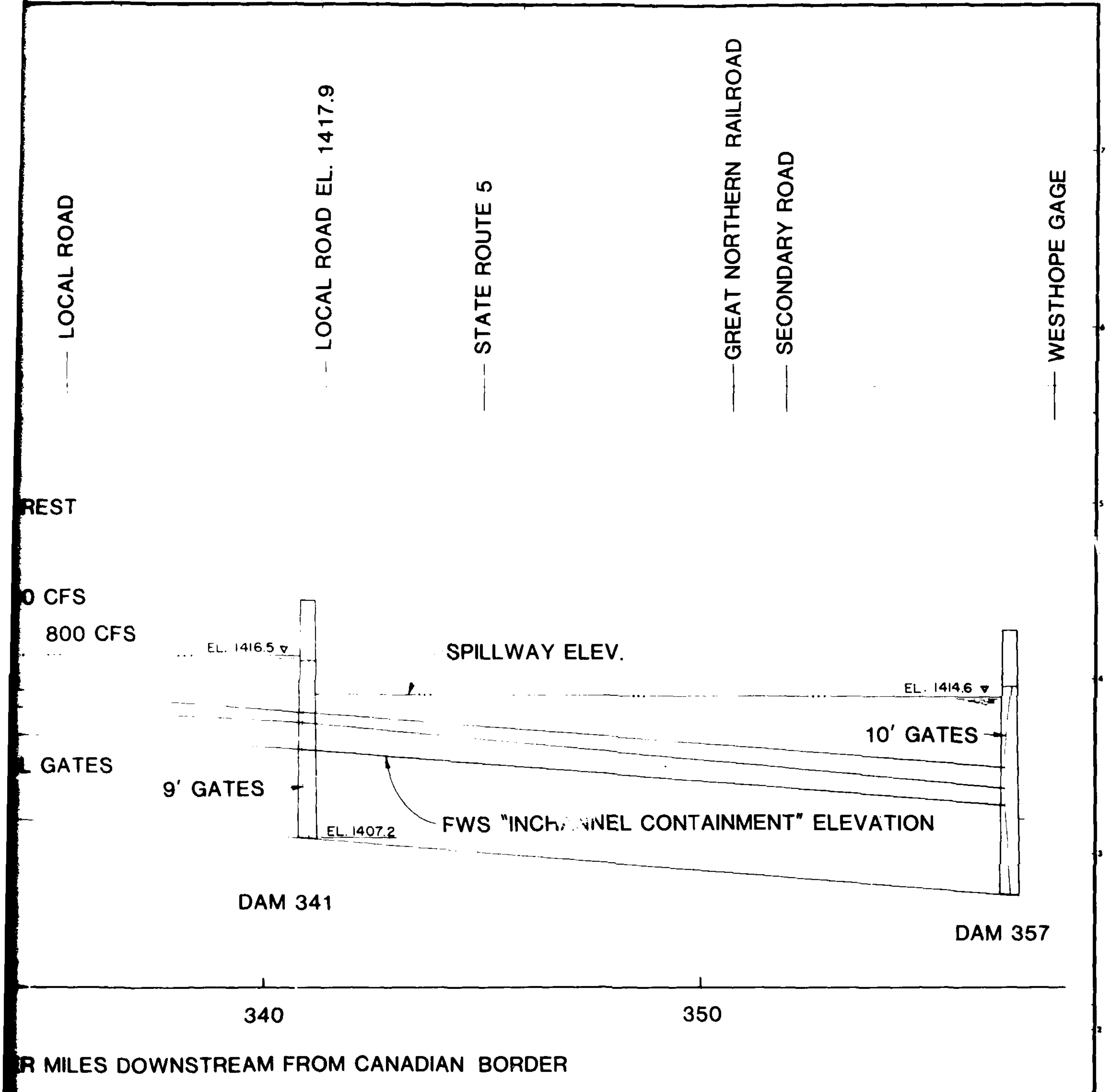
SYMBOL / DESCRIPTION / DATE / APPROVAL	
	DEPARTMENT OF THE ARMY ST PAUL DISTRICT, CORPS OF ENGINEERS ST PAUL, MINNESOTA
DESIGNED BY: B J B DRAWN BY: JRJ CHECKED BY: G R S	DESIGN MEMORANDUM NO 3 GENERAL FLOOD CONTROL-LAKE DARLING SOURIS RIVER, NORTH DAKOTA UPPER SOURIS REFUGE TYPICAL STRUCTURES
SUBMITTED BY: [signature] APPROVED BY: [signature]	DATE: JUNE 1983
	SCALE AS SHOWN
	DRAWING NUMBER RI-R-5/649 SHEET OF

PLATE NO. 19

1 2



FREEMAN BRIDGE ROAD AT EL. 1425.1
STATE ROUTE 14 EL. 1424.0
LOCAL ROAD EL. 1422.1
SOO LINE RAILROAD
LOCAL ROAD
EL. 1427.5
EL. 1428.0
EL. 1425.1
DAM CREST
EL. 1421.0
EL. 1418.5
600 CFS
800 CFS
EL. 1416.5
10' GATES
7' GATES
EL. 1415.6
EL. 1414.2
DAM 320
DAM 326
9' GATES
RADIAL GATES
9' GATES
EL. 1408.6
DAM 332
DAM 3
1430
1420
1410
1400
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
320
330
340
RIVER MILES DOWNSTREAM FR



SYMBOL | DESCRIPTION | DATE | APPROVAL

DESIGNED BY B.J.B.
DRAWN BY DIE
CHECKED BY G.R.S.
SUBMITTED BY:
APPROVED

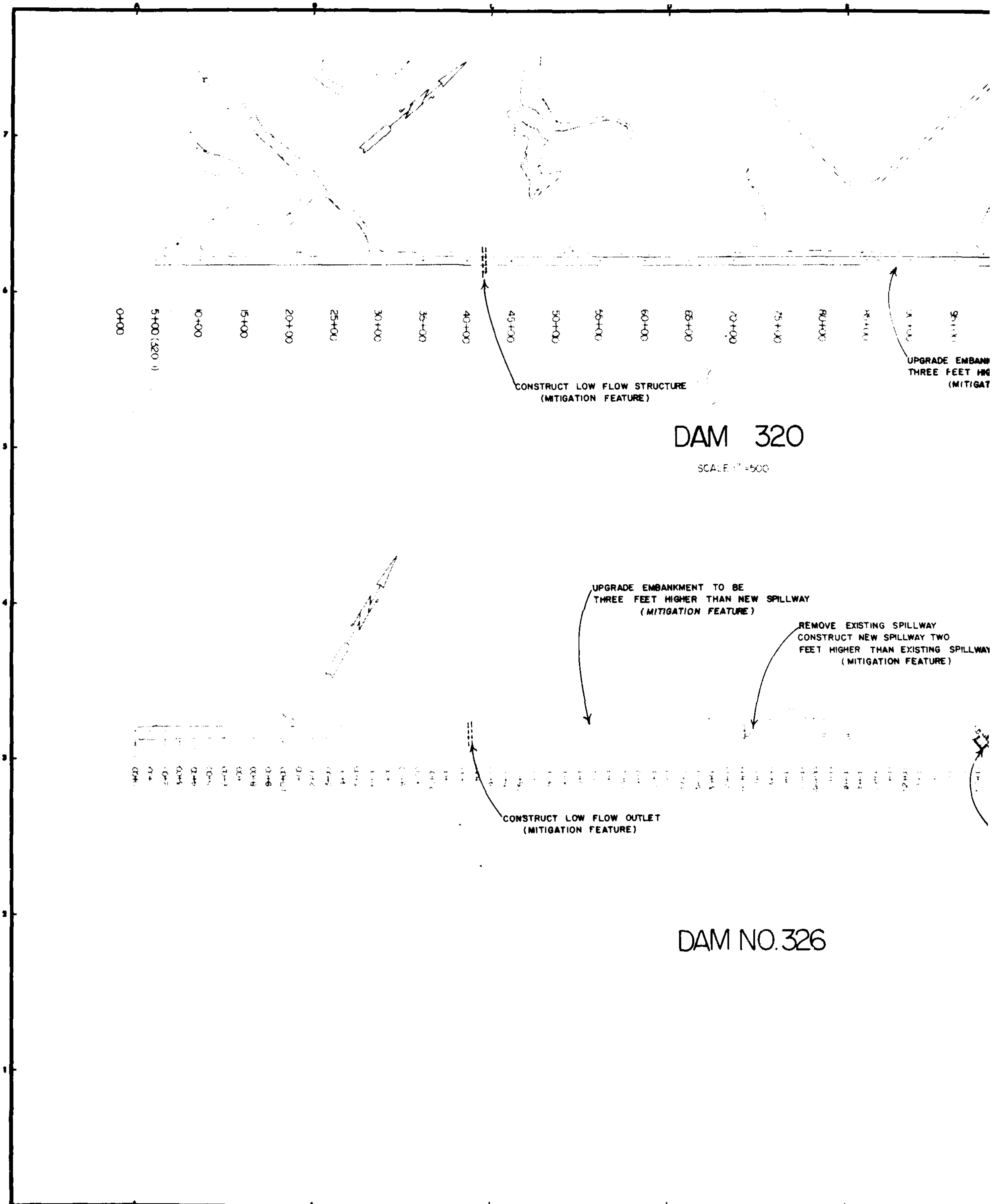
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
SCHEMATIC PROFILE
J. CLARK SALYER II NATIONAL WILDLIFE REFUGE

DATE JUNE 1983
SCALE AS SHOWN
DRAWING NUMBER RI-R-5/650
SHEET OF

SAFETY PAYS

PLATE NO.20

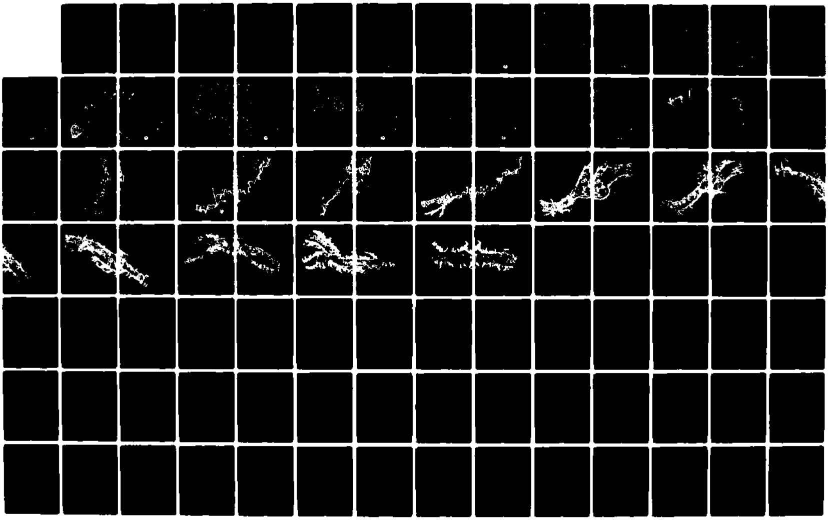
1 2

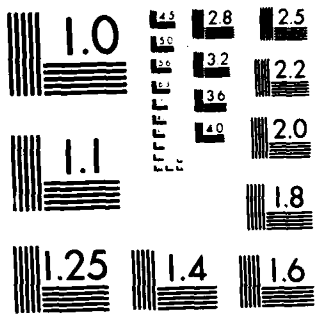


0+00
5+00 (320 1)
10+00
15+00
20+00
25+00
30+00
35+00
40+00
45+00
50+00
55+00
60+00
65+00
70+00
75+00
80+00
CONSTRUCT LOW FLOW STRUCTURE
(MITIGATION FEATURE)
UPGRADE EMBANK
THREE FEET HIG
(MITIGAT
DAM 320
UPGRADE EMBANKMENT TO BE
THREE FEET HIGHER THAN NEW SPILLWAY
(MITIGATION FEATURE)
REMOVE EXISTING SPILLWAY
CONSTRUCT NEW SPILLWAY TWO
FEET HIGHER THAN EXISTING SPILLWAY
(MITIGATION FEATURE)
CONSTRUCT LOW FLOW OUTLET
(MITIGATION FEATURE)
DAM NO. 326

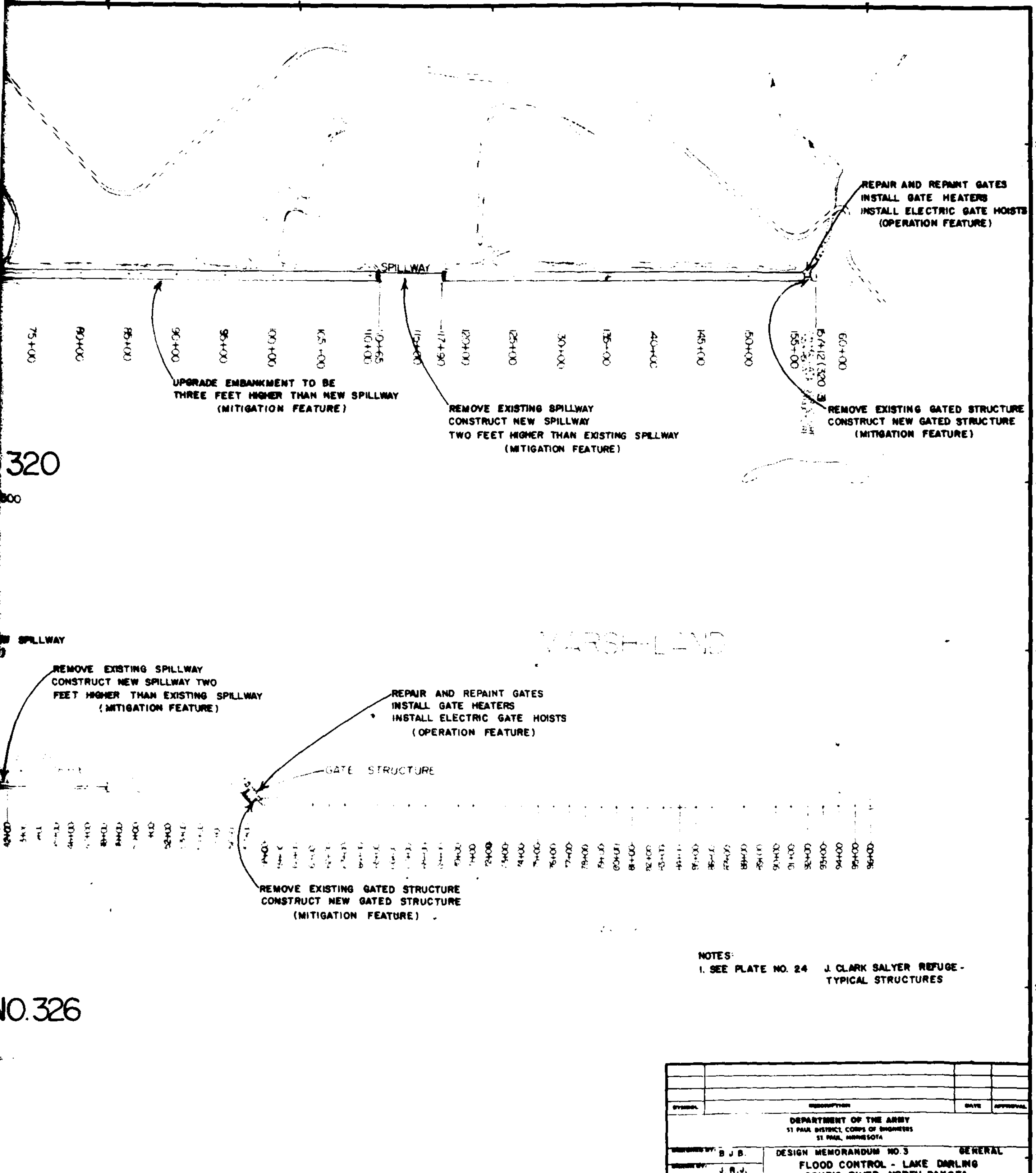
AD-A136 228 LAKE DARLING FLOOD CONTROL PROJECT SOURIS RIVER NORTH DAKOTA GENERAL PROJECT DESIGN(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT JUN 83 3/7

UNCLASSIFIED F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A



NOTES:
1. SEE PLATE NO. 24 J. CLARK SALYER REFUGE - TYPICAL STRUCTURES

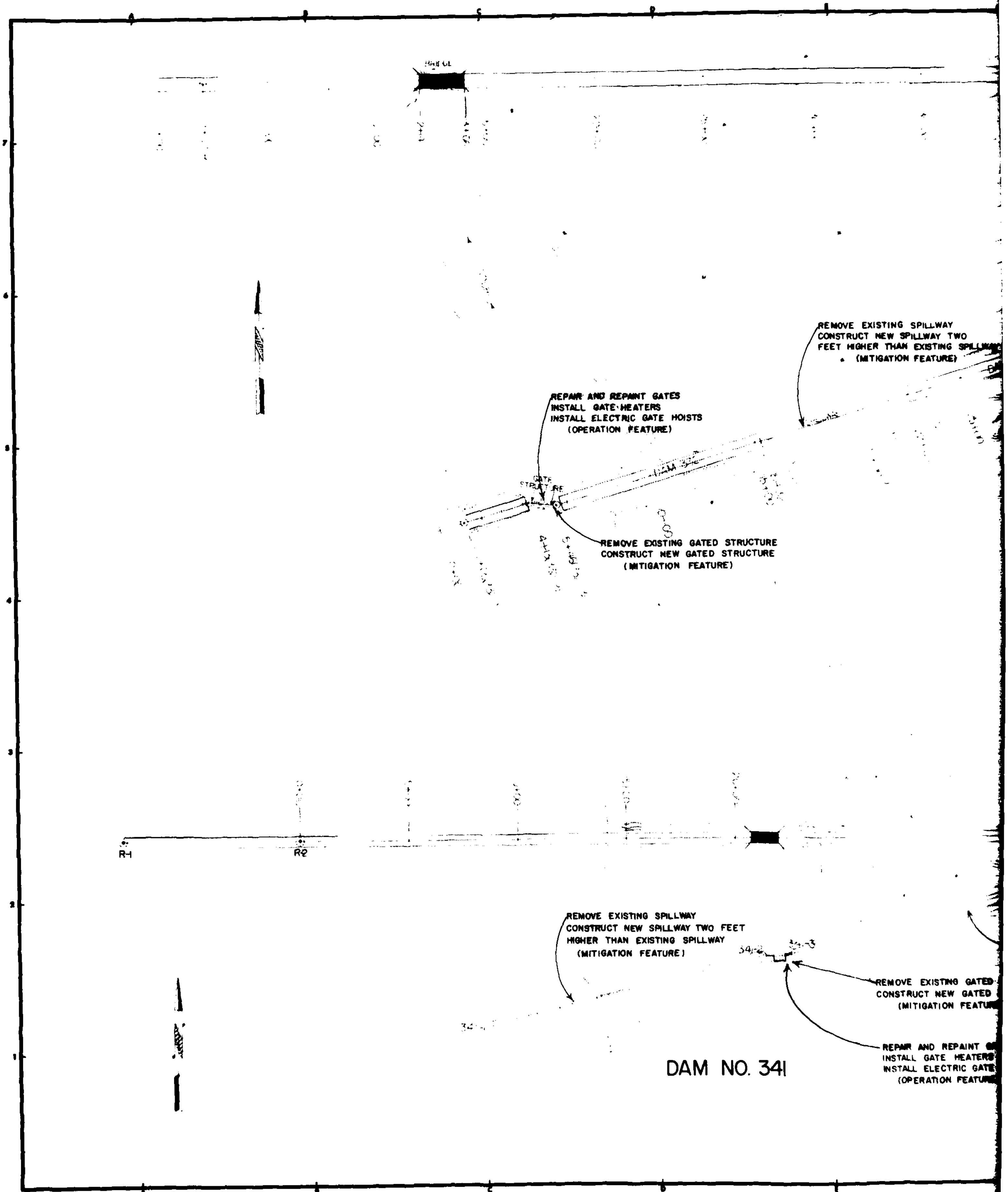
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: B.J.B.
DRAWN BY: J.R.J.
CHECKED BY: G.R.S.
SUBMITTED BY:
APPROVED:

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
J. CLARK SALYER REFUGE
DAMS 320 AND 326

DATE: JUNE 1983
SCALE: AS SHOWN
DRAWING NUMBER: RI-R-5/651

PLATE NO. 21



REMOVE EXISTING SPILLWAY
CONSTRUCT NEW SPILLWAY TWO
FEET HIGHER THAN EXISTING SPILLWAY
(MITIGATION FEATURE)
REPAIR AND REPAINT GATES
INSTALL GATE HEATERS
INSTALL ELECTRIC GATE HOISTS
(OPERATION FEATURE)
GATE STRUCTURE
REMOVE EXISTING GATED STRUCTURE
CONSTRUCT NEW GATED STRUCTURE
(MITIGATION FEATURE)
R-1
R2
REMOVE EXISTING SPILLWAY
CONSTRUCT NEW SPILLWAY TWO FEET
HIGHER THAN EXISTING SPILLWAY
(MITIGATION FEATURE)
REMOVE EXISTING GATED
CONSTRUCT NEW GATED
(MITIGATION FEATURE
REPAIR AND REPAINT
INSTALL GATE HEATERS
INSTALL ELECTRIC GATE
(OPERATION FEATURE
DAM NO. 341

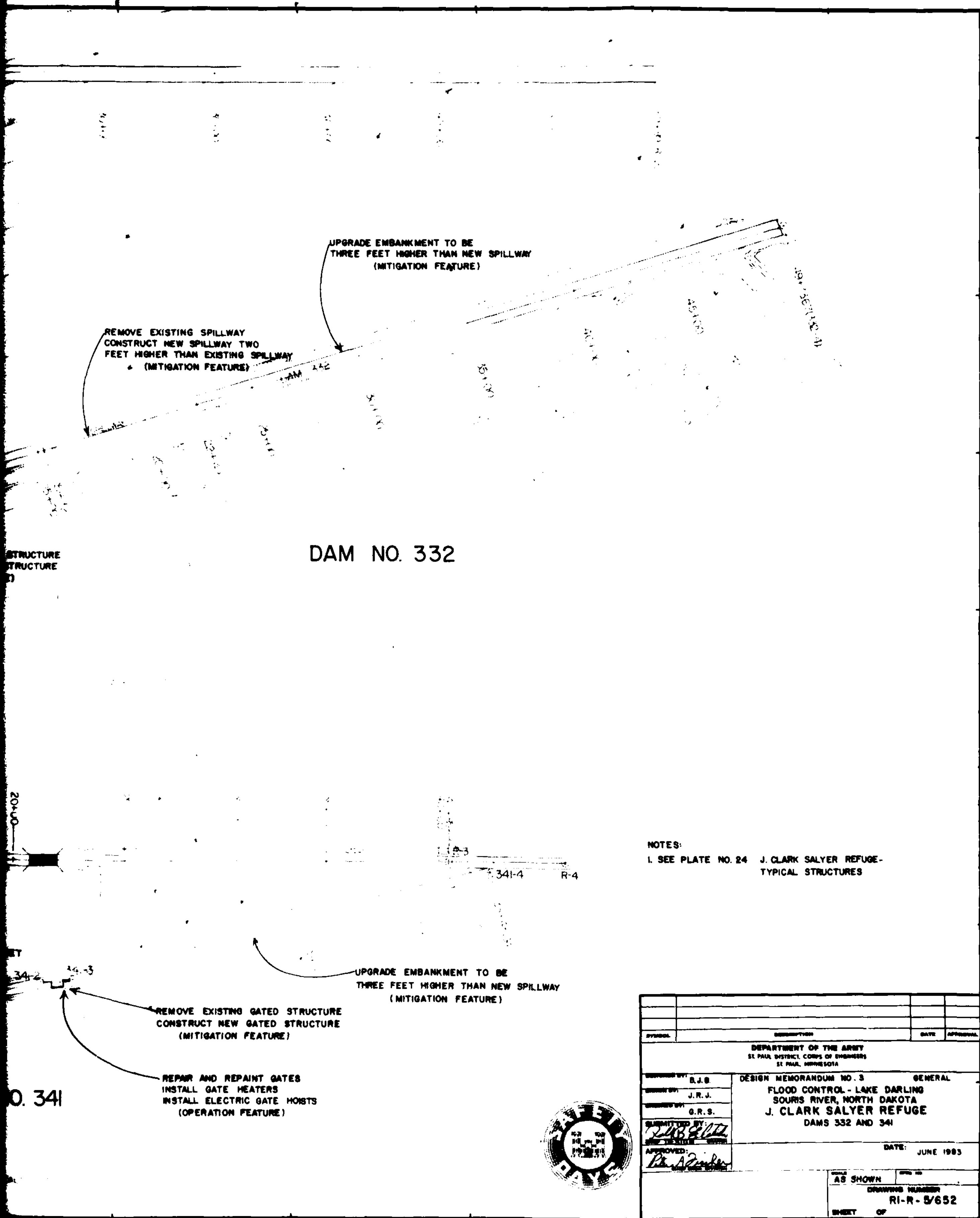
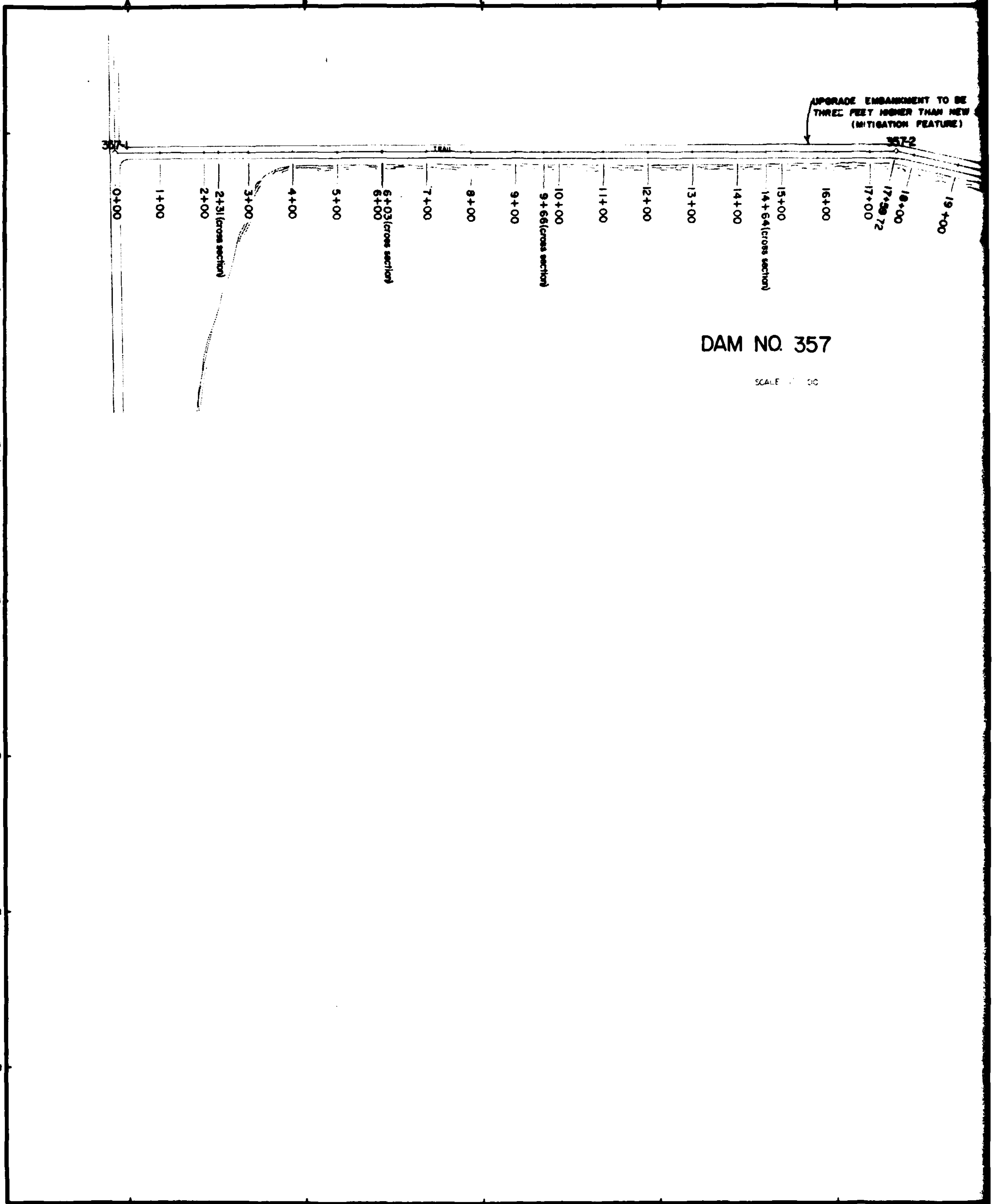
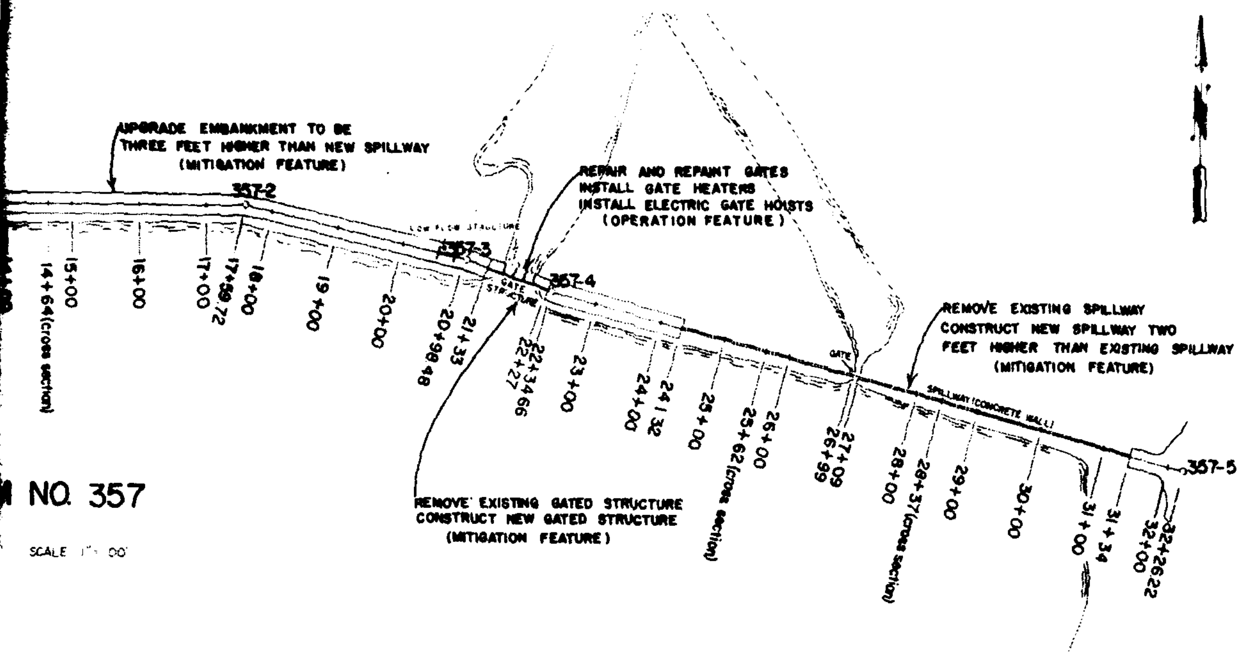


PLATE NO. 22

1 2


UPGRADE EMBANKMENT TO BE
THREE FEET HIGHER THAN NEW
(MITIGATION FEATURE)
357-1
357-2
0+00
1+00
2+00
2+31 (cross section)
3+00
4+00
5+00
6+00
6+03 (cross section)
7+00
8+00
9+00
9+66 (cross section)
10+00
11+00
12+00
13+00
14+00
14+64 (cross section)
15+00
16+00
17+00
17+59.72
18+00
19+00
DAM NO. 357



DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

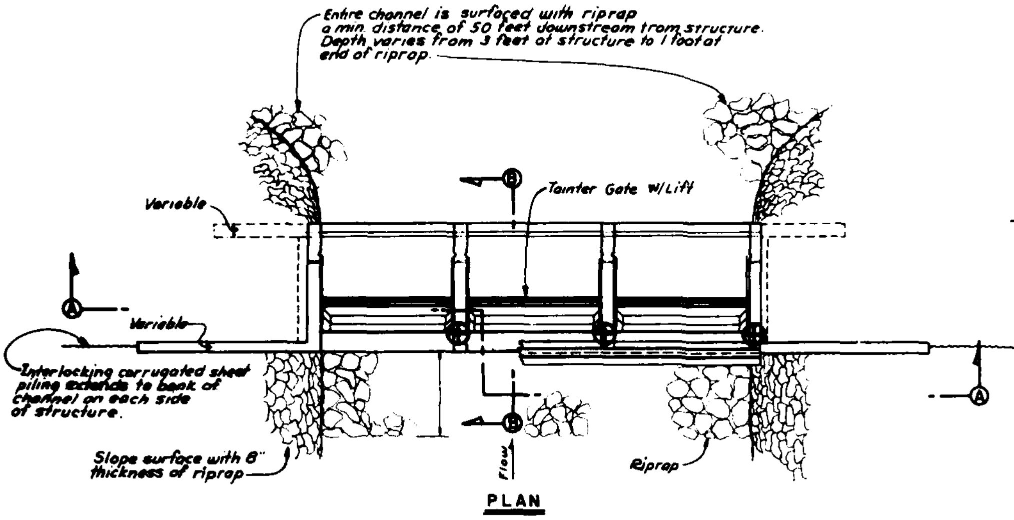
B.J.B.	DESIGN MEMORANDUM NO. 3 GENERAL
J.R.J.	FLOOD CONTROL - LAKE DARLING
G.R.S.	SOURIS RIVER, NORTH DAKOTA
	J. CLARK SALYER REFUGE
	DAM 357

DATE: JUNE 1983

DRAWING NUMBER R-R-5/653

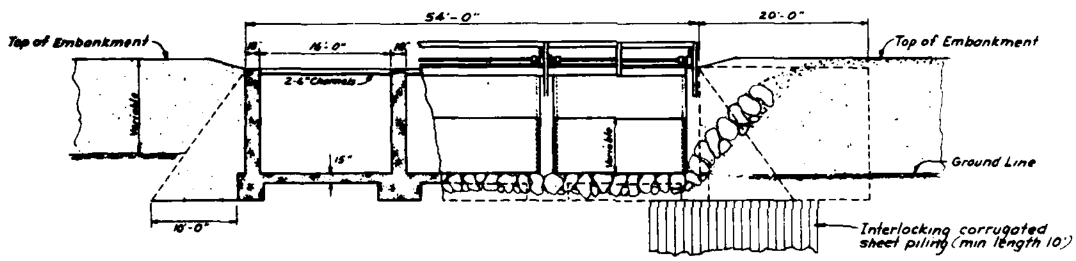
PLATE NO. 23

1 2



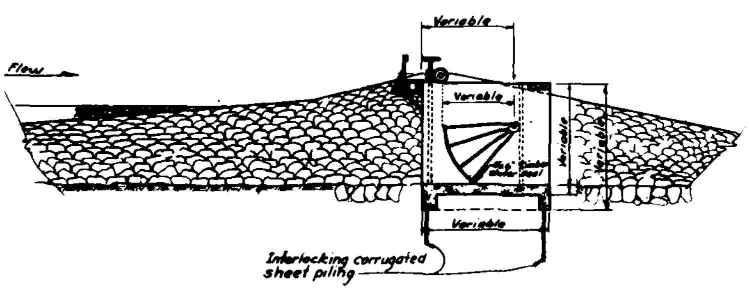
PLAN

SCALE IN FEET



ELEVATION SECTION A-A

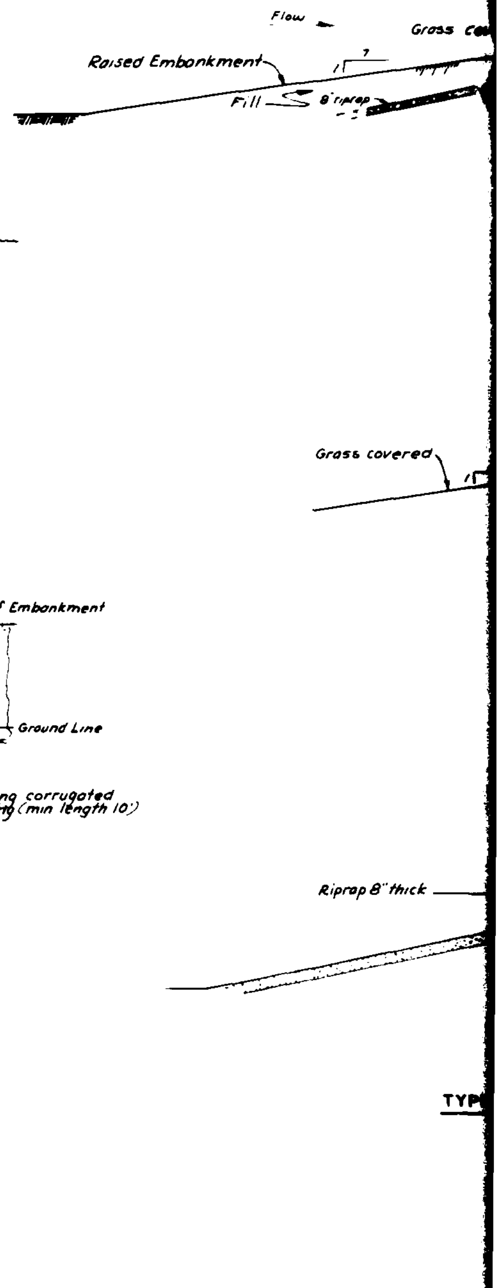
SCALE IN FEET



SECTION B-B

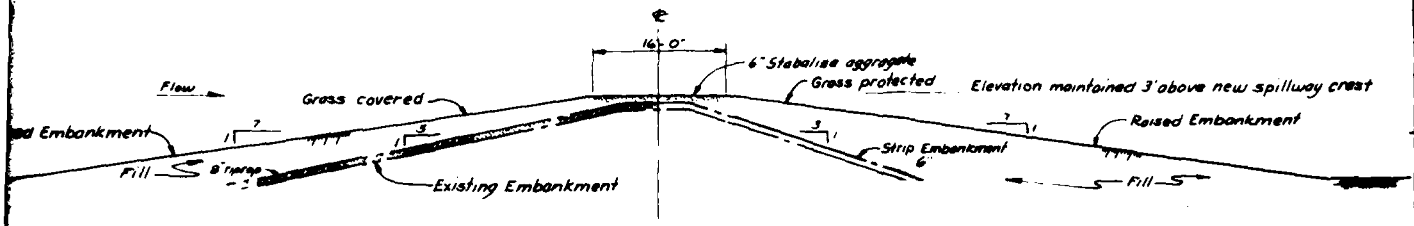
SCALE IN FEET

TYPICAL EXISTING GATE STRUCTURE



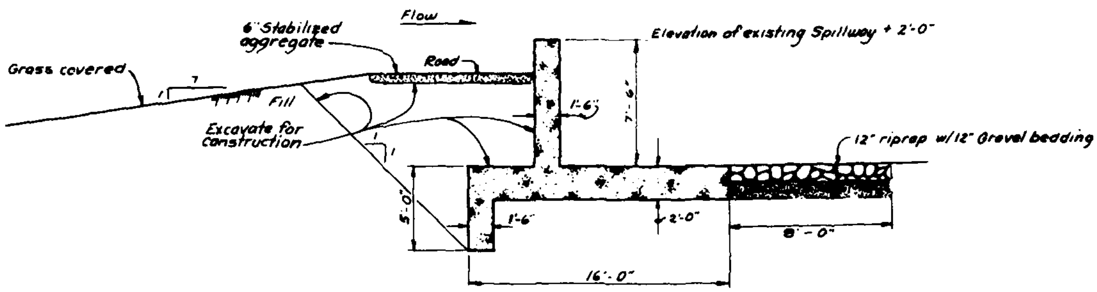
GATE TABLES

STRUCTURE	GATES Size ft.	No.	FLOOR Length
320	10x16	3	17 ft
326	7x16	3	15 ft
332	9x16	3	16 ft
341	9x16	3	16 ft
357	10x16	3	18 ft



TYPICAL RAISED AND EXISTING EMBANKMENT SECTION

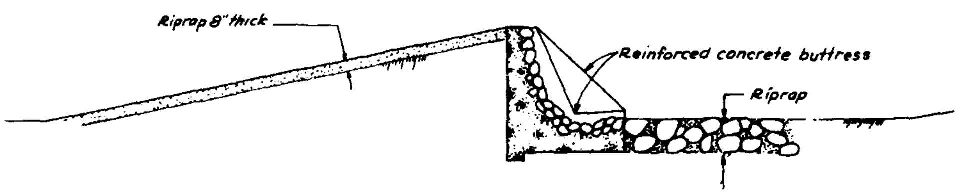
SCALE IN FEET



TYPICAL NEW SPILLWAY SECTION

(DIMENSIONS FOR DAM 320, OTHERS ARE SIMILAR)

SCALE IN FEET



TYPICAL EXISTING RUBBLE MASONRY SPILLWAY SECTION

SCALE IN FEET

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

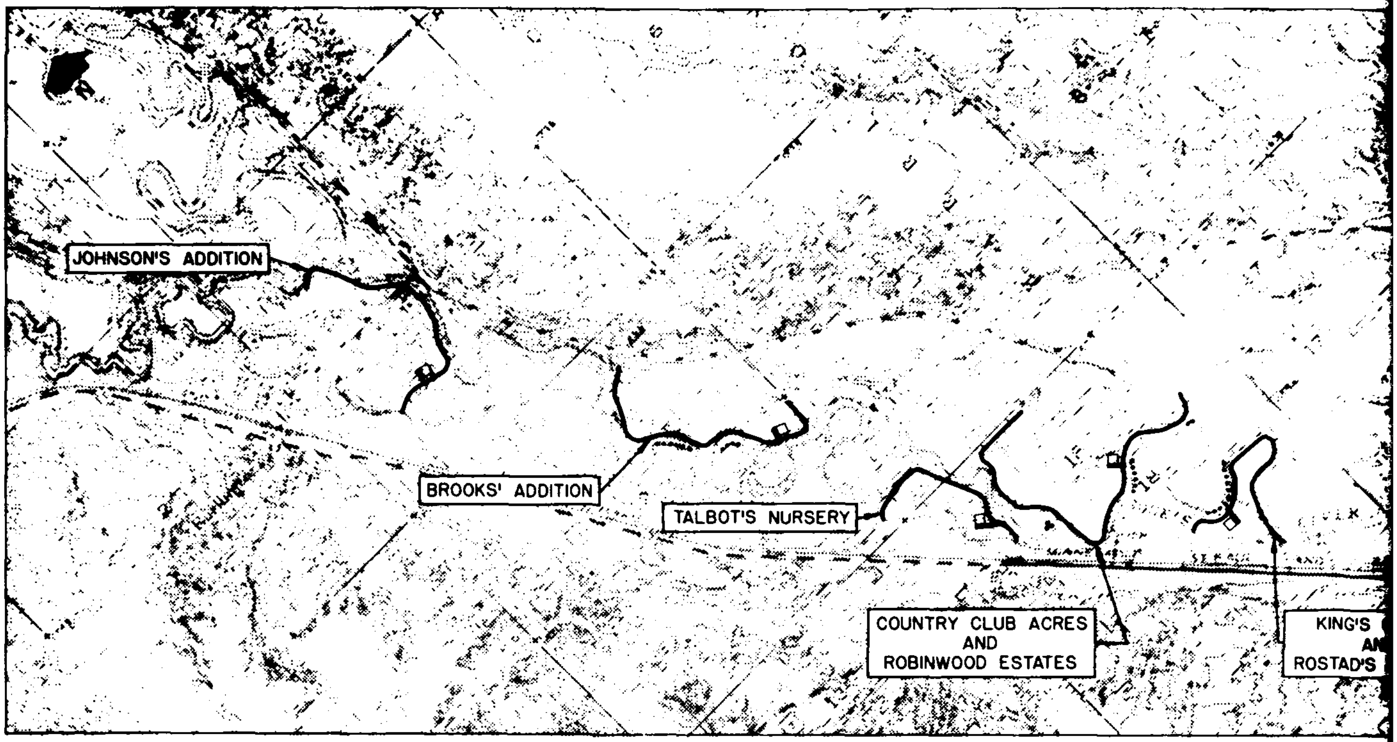
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
J. CLARK SALYER REFUGE
TYPICAL STRUCTURES

B J B
JU
G.R.S.
SUBMITTED BY:
APPROVED BY:

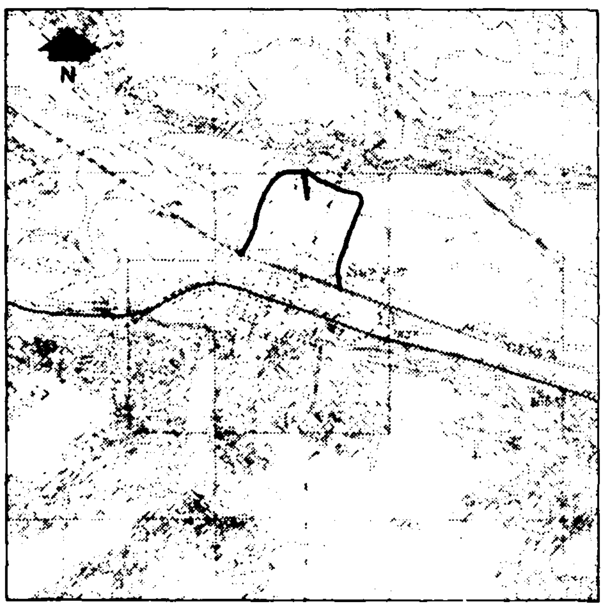
DATE: JUNE 1963
SCALE: AS SHOWN
DRAWING NUMBER: RI-R-5/654
SHEET OF

SAFETY PAYS

PLATE NO. 24



SOURIS RIVER REACH F – BETWEEN BURLINGTON AND



SOURIS RIVER REACH AT SAWYER

LEGEND

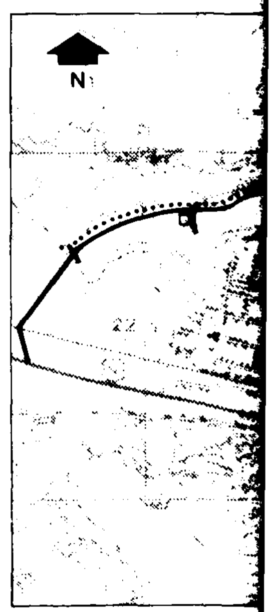
LEVEE ALIGNMENT

CHANNEL MODIFICATION

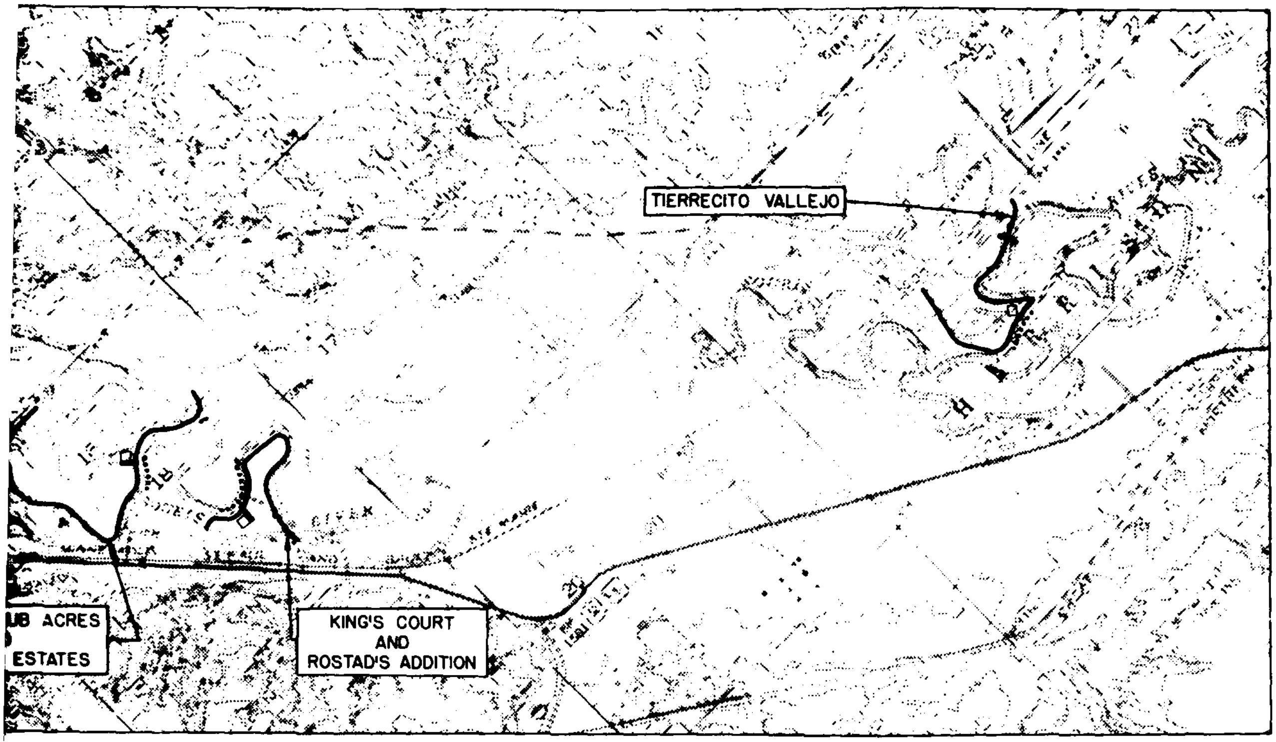
PUMPING STATION SITE

GRAVITY OUTLET

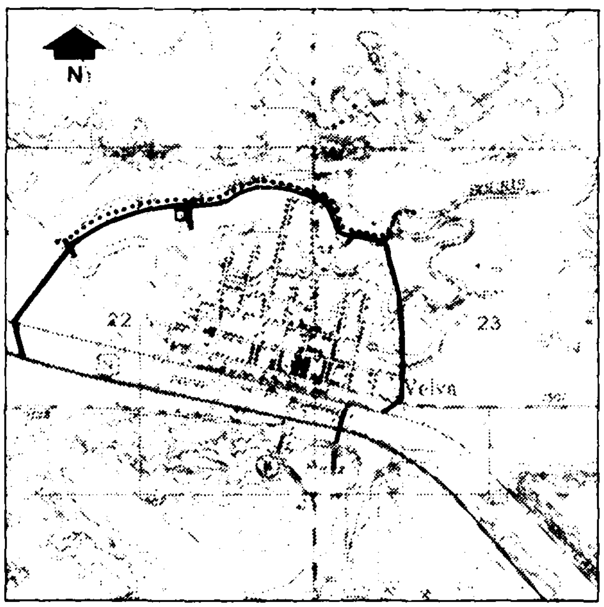
SCALE 0 1000 2000 3000 4000 FEET



SOURIS RIV



EACH F – BETWEEN BURLINGTON AND MINOT



SOURIS RIVER REACH AT VELVA

DO FEET

DEPARTMENT OF THE ARMY
ST PAUL DISTRICT CORPS OF ENGINEERS
ST PAUL, MINNESOTA

W.M. L.H.B. J.J.F.
J.M.J.
M.M.B. A.M.K. J.W.M.

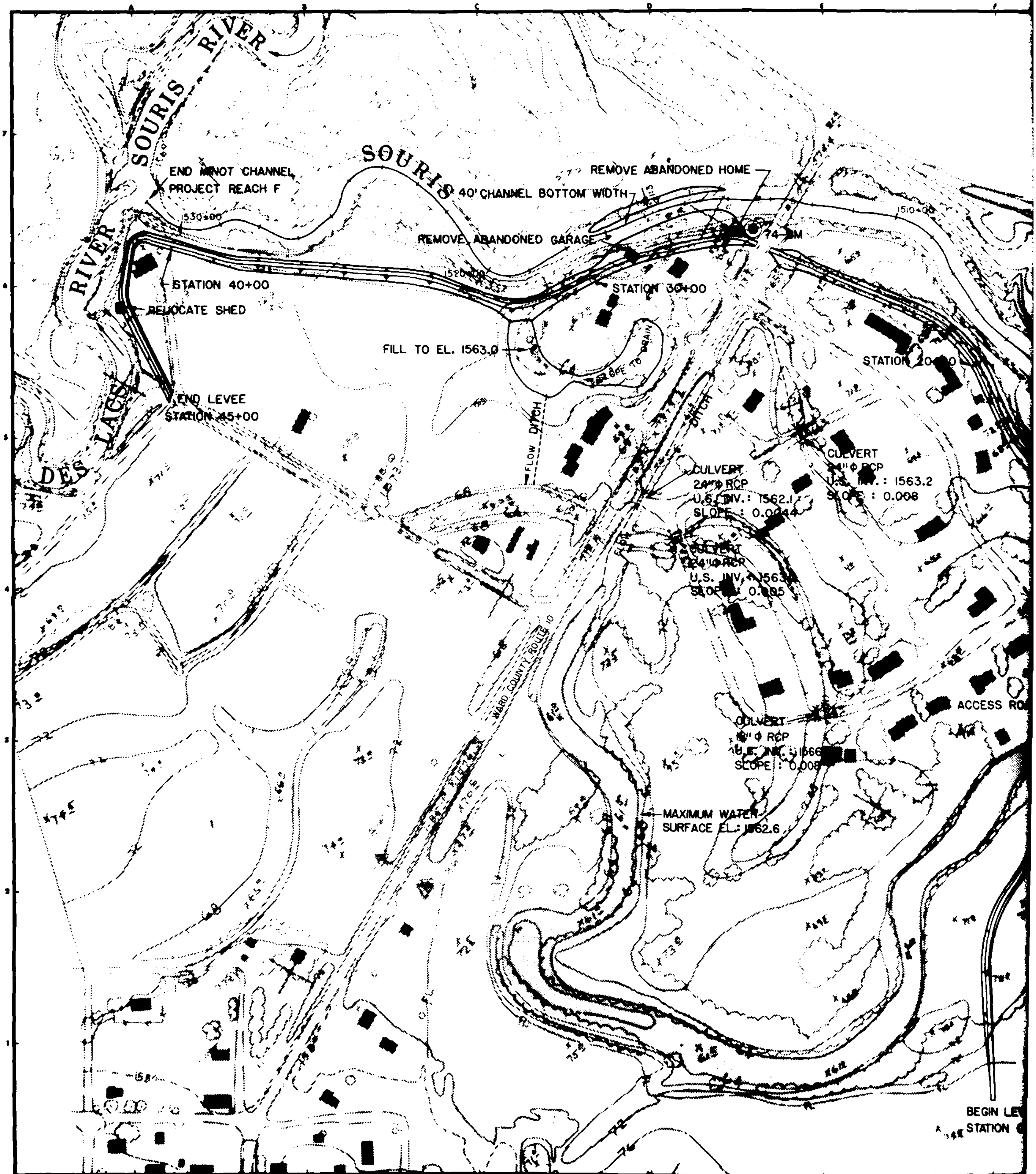
DESIGN MEMORANDUM NO 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
GENERAL PLAN
MAJOR DOWNSTREAM WORKS

DATE:
JUNE 1983

DRAWING NUMBER
RI-R-5/655

PLATE NO. 25

1 7



SOURIS RIVER
SOURIS
RIVER DES LACS
END MINOT CHANNEL PROJECT REACH F
1530+00
1520+00
1510+00
REMOVE ABANDONED HOME
40' CHANNEL BOTTOM WIDTH
REMOVE ABANDONED GARAGE
STATION 40+00
RELOCATE SHED
STATION 30+00
FILL TO EL. 1563.0
SLOPE TO DRAIN
END LEVEE
STATION 45+00
FLOW DITCH
DITCH
CULVERT
24"Φ RCP
U.S. INV.: 1563.2
SLOPE : 0.008
CULVERT
24"Φ RCP
U.S. INV.: 1562.1
SLOPE : 0.0044
CULVERT
24"Φ RCP
WARD COUNTY ROUTE 10
CULVERT
18"Φ RCP
MAXIMUM WATER SURFACE EL.: 1562.6

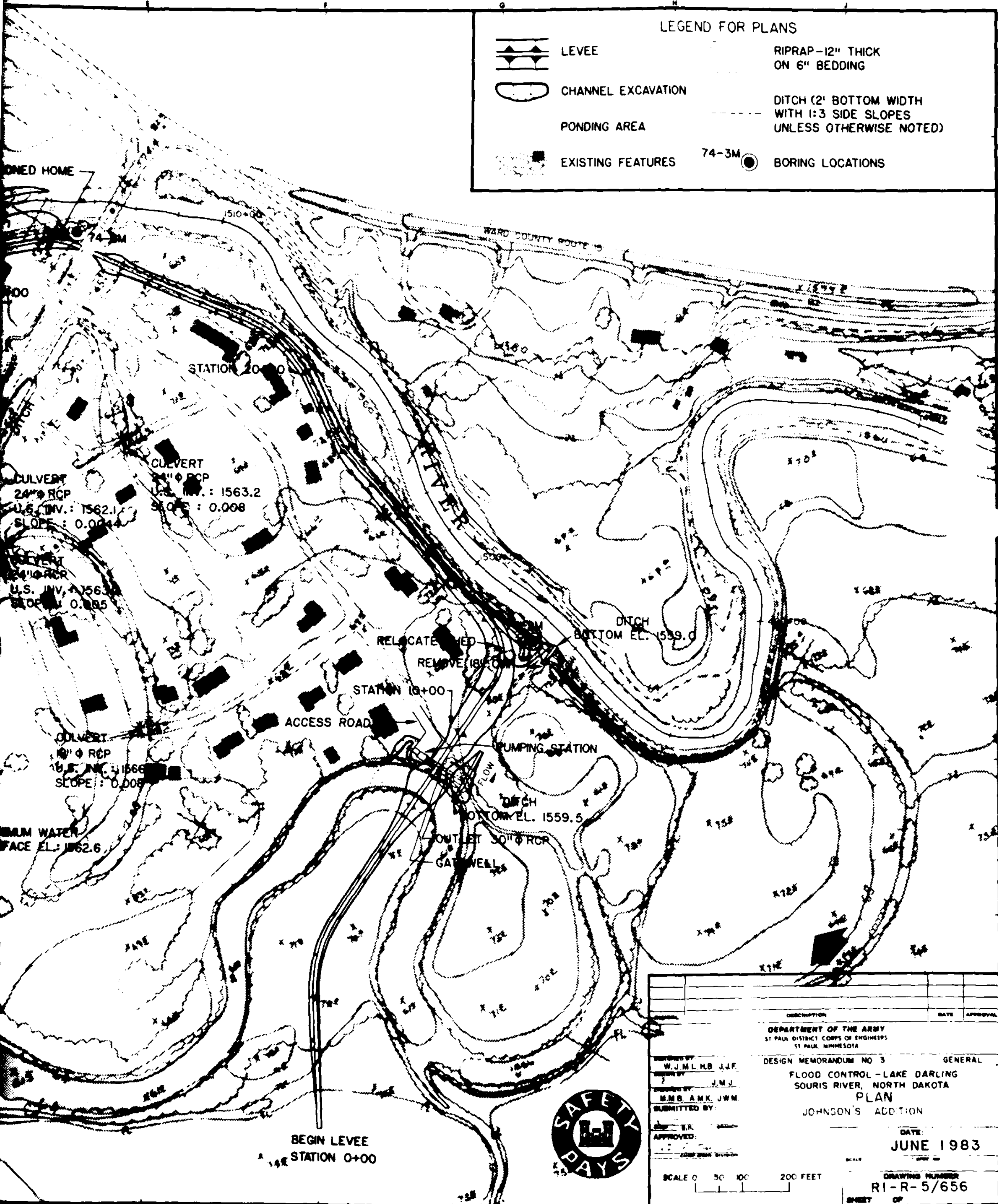
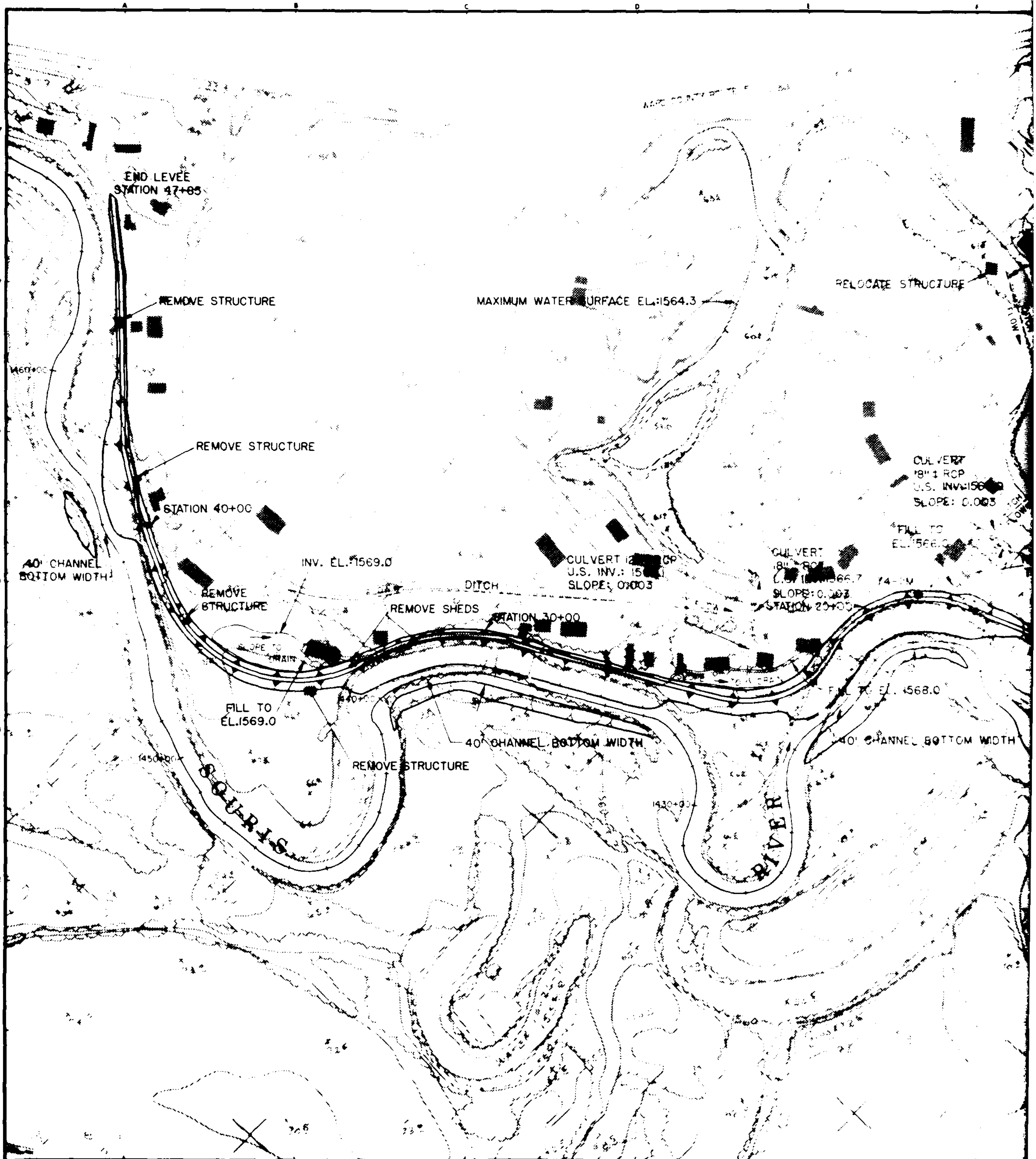
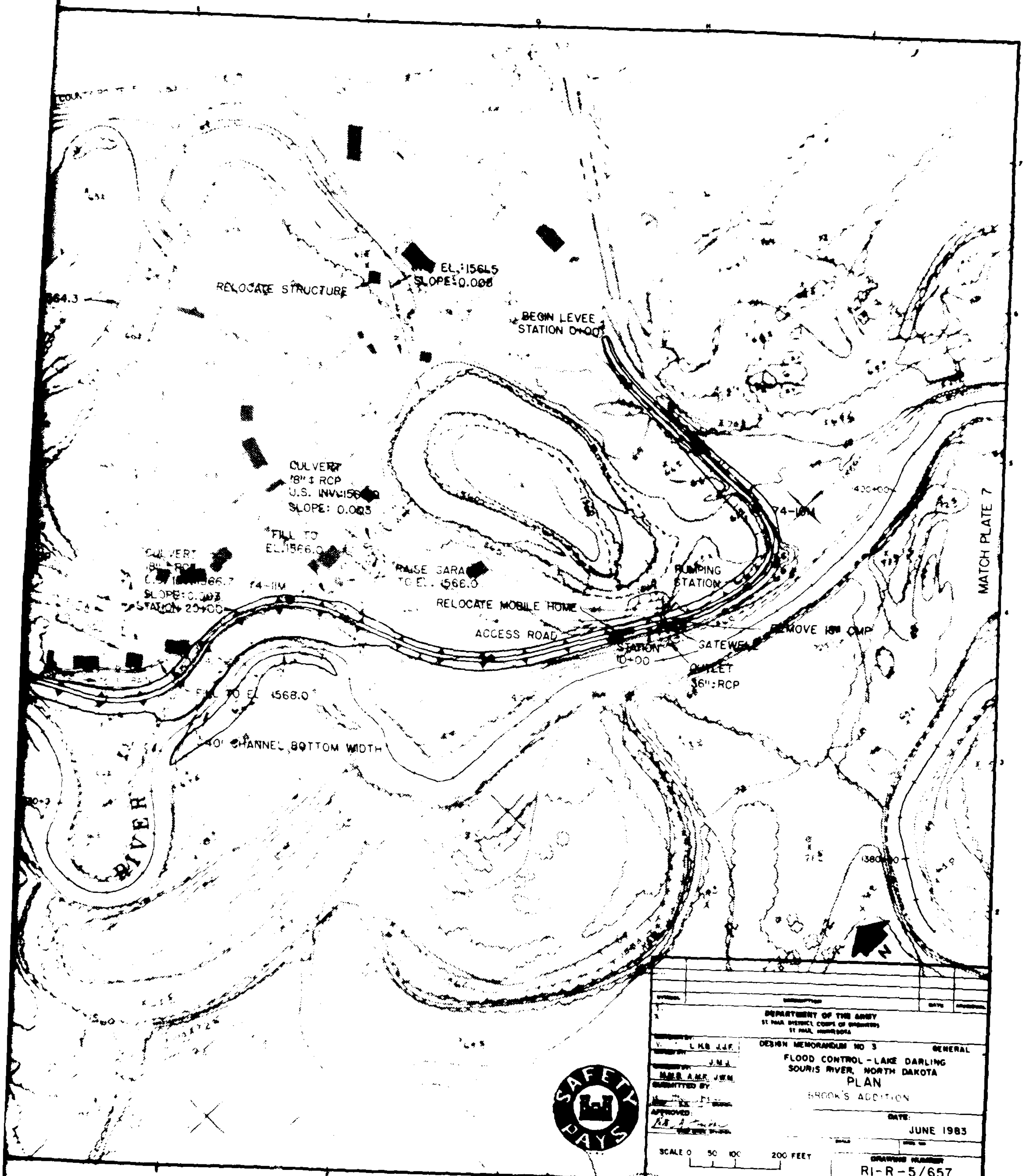

LEGEND FOR PLANS
LEVEE
CHANNEL EXCAVATION
PONDING AREA
EXISTING FEATURES
RIPRAP-12" THICK ON 6" BEDDING
DITCH (2' BOTTOM WIDTH WITH 1:3 SIDE SLOPES UNLESS OTHERWISE NOTED)
74-3M
BORING LOCATIONS
WARD COUNTY ROUTE 15
STATION 20+00
CULVERT 24"Φ RCP U.S. INV.: 1563.2 SLOPE: 0.008
CULVERT 24"Φ RCP U.S. INV.: 1562.1 SLOPE: 0.0044
RIVER
DITCH BOTTOM EL. 1559.0
RELOCATE SHED
STATION 10+00
ACCESS ROAD
PUMPING STATION
FLOW
DITCH BOTTOM EL. 1559.5
OUTLET 30"Φ RCP
GATEWELL
CULVERT 18"Φ RCP
BEGIN LEVEE STATION 0+00
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT CORPS OF ENGINEERS
ST. PAUL, MINNESOTA
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
PLAN
JOHNSON'S ADDITION
W.J.M.L.H.B. J.J.F.
J.M.J.
M.M.B. A.M.K. J.W.M.
SUBMITTED BY:
APPROVED:
DATE:
JUNE 1983
SCALE 0 50 100 200 FEET
DRAWING NUMBER
RI-R-5/656
SAFETY PAYS

PLATE NO. 26



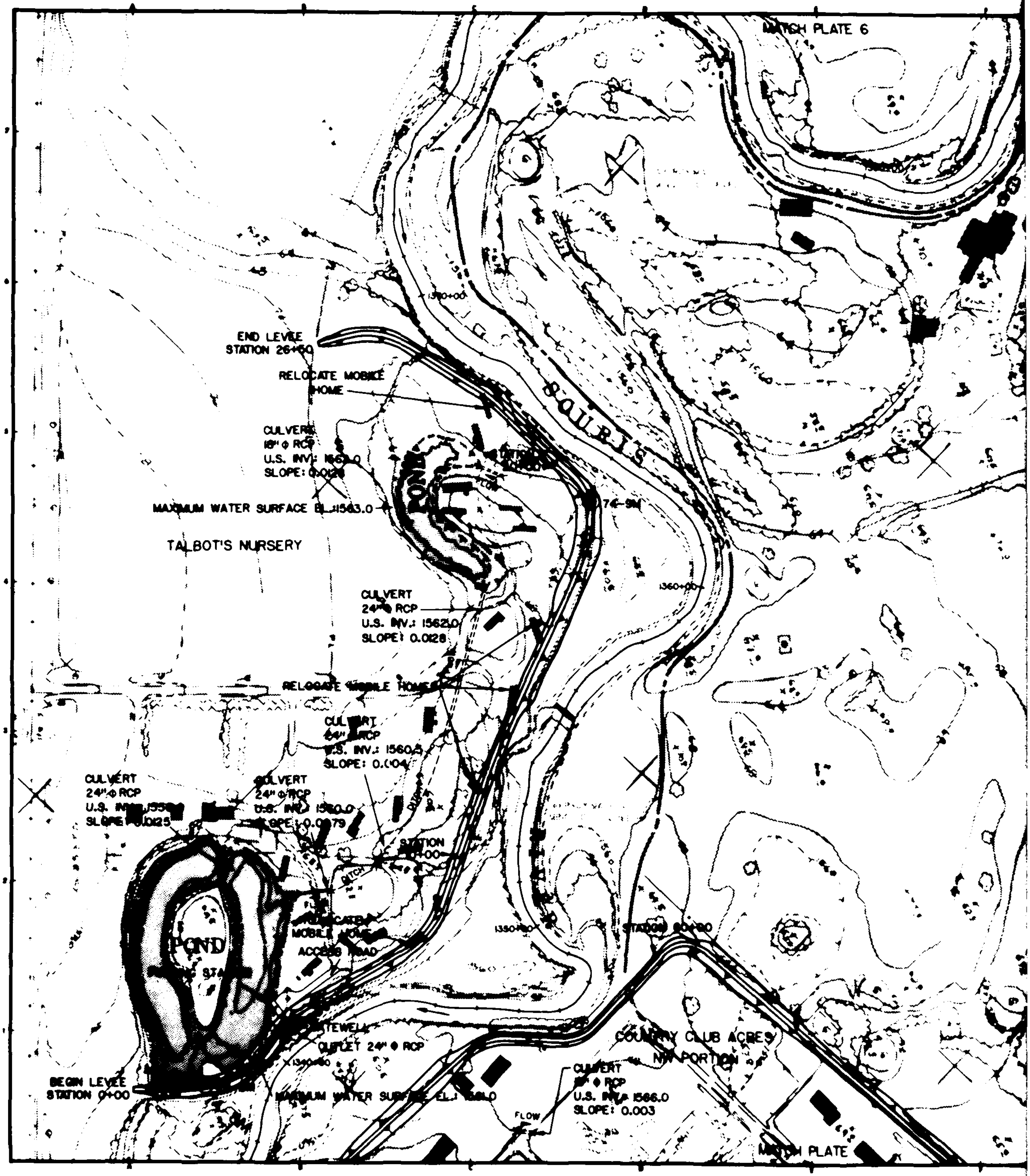
END LEVEE
STATION 47+85
REMOVE STRUCTURE
MAXIMUM WATER SURFACE EL.1564.3
RELOCATE STRUCTURE
REMOVE STRUCTURE
STATION 40+00
40' CHANNEL
BOTTOM WIDTH
INV. EL. 1569.0
DITCH
REMOVE
STRUCTURE
REMOVE SHEDS
STATION 30+00
CULVERT
U.S. INV.
SLOPE: 0.003
CULVERT
SLOPE: 0.003
CULVERT
18" RCP
SLOPE: 0.003
FILL TO
EL. 1569.0
REMOVE STRUCTURE
40' CHANNEL BOTTOM WIDTH
FILL TO EL. 1568.0
40' CHANNEL BOTTOM WIDTH
SOURIS
RIVER



RELOCATE STRUCTURE
EL. 1566.5
SLOPE: 0.008
BEGIN LEVEE
STATION 0+00
CULVERT
18" RCP
SLOPE: 0.003
FILL TO
SLOPE: 0.003
STATION 25+00
74-11M
RAISE GARAGE
RELOCATE MOBILE HOME
ACCESS ROAD
PUMPING STATION
STATION 10+00
GATEWELL
REMOVE 18" CMP
OUTLET
36" RCP
74-11M
FILL TO EL. 1568.0
40' CHANNEL BOTTOM WIDTH
RIVER
MATCH PLATE 7
N
SAFETY PAYS
DEPARTMENT OF THE ARMY
DESIGN MEMORANDUM NO 3
GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
PLAN
BROOK'S ADDITION
DATE:
JUNE 1983
SCALE 0 50 100 200 FEET
DRAWING NUMBER
RI-R-5/657

PLATE NO. 27

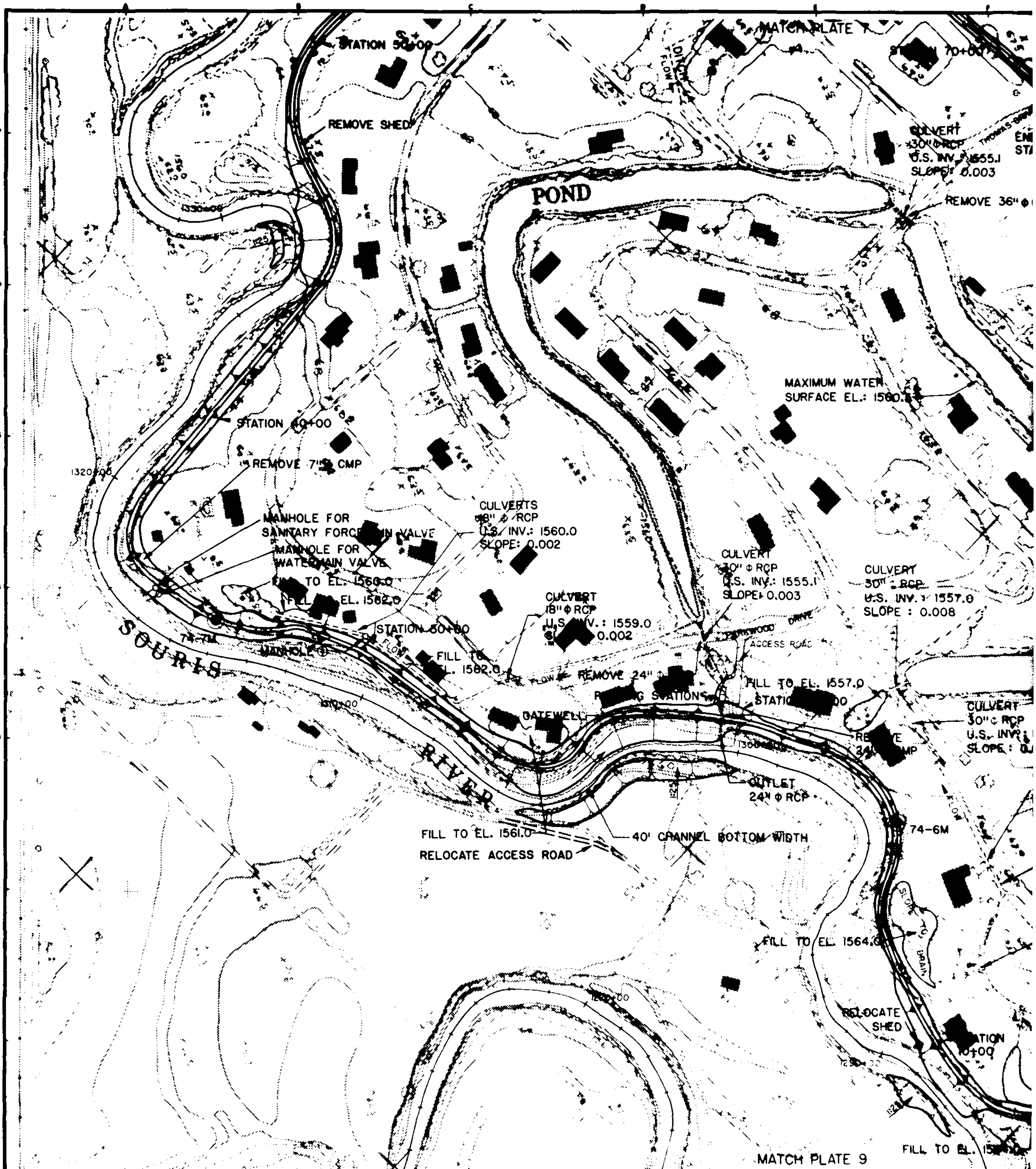
2


MATCH PLATE 6
END LEVEE
STATION 26+50
RELOCATE MOBILE
HOME
SOURIS
TALBOT'S NURSERY
MAXIMUM WATER SURFACE EL.:1563.0
CULVERT
24" Φ RCP
U.S. INV.: 1562.0
SLOPE: 0.0128
RELOCATE MOBILE HOMES
CULVERT
24" Φ RCP
U.S. INV.: 1560.5
SLOPE: 0.004
CULVERT
24" Φ RCP
CULVERT
24" Φ RCP
U.S. INV.: 1560.0
STATION
POND
BEGIN LEVEE
STATION 0+00
OUTLET 24" Φ RCP
ACCESS ROAD
STATION 50+00
COUNTRY CLUB ACRES
NW PORTION
CULVERT
18" Φ RCP
U.S. INV.: 1566.0
SLOPE: 0.003
FLOW
MATCH PLATE


MATCH PLATE 6
ACRES
MATCH PLATE
N
DEPARTMENT OF THE ARMY
DESIGN MEMORANDUM NO. 3
GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
PLAN
TALBOT'S NURSERY AND
COUNTRY CLUB ACRES
DATE:
JUNE 1983
SCALE 0 50 100 200 FEET
RI-R-5/658
SAFETY PAYS

PLATE NO. 28

2


MATCH PLATE 7
STATION 50+00
REMOVE SHED
POND
CULVERT
30" Φ RCP
U.S. INV.: 1555.1
SLOPE : 0.003
REMOVE 36" Φ
MAXIMUM WATER
SURFACE EL.: 1560.
STATION 40+00
REMOVE 7' CMP
MANHOLE FOR
SANITARY FORCE MAIN VALVE
MANHOLE FOR
WATERMAIN VALVE
FILL TO EL. 1560.0
FILL TO EL. 1562.0
CULVERTS
18" Φ RCP
U.S. INV.: 1560.0
SLOPE: 0.002
CULVERT
18" Φ RCP
U.S. INV.: 1559.0
0.002
CULVERT
30" Φ RCP
U.S. INV.: 1555.1
SLOPE: 0.003
CULVERT
30" Φ RCP
U.S. INV.: 1557.0
SLOPE : 0.008
SOURIS
RIVER
STATION 30+00
MANHOLE
FILL TO
EL. 1562.0
REMOVE 24"
PARKWOOD DRIVE
ACCESS ROAD
FILL TO EL. 1557.0
GATEWELL
CULVERT
30" Φ RCP
OUTLET
24" Φ RCP
FILL TO EL. 1561.0
RELOCATE ACCESS ROAD
40' CHANNEL BOTTOM WIDTH
74-6M
74-7M
FILL TO EL. 1564.0
RELOCATE
SHED
MATCH PLATE 9
FILL TO EL.

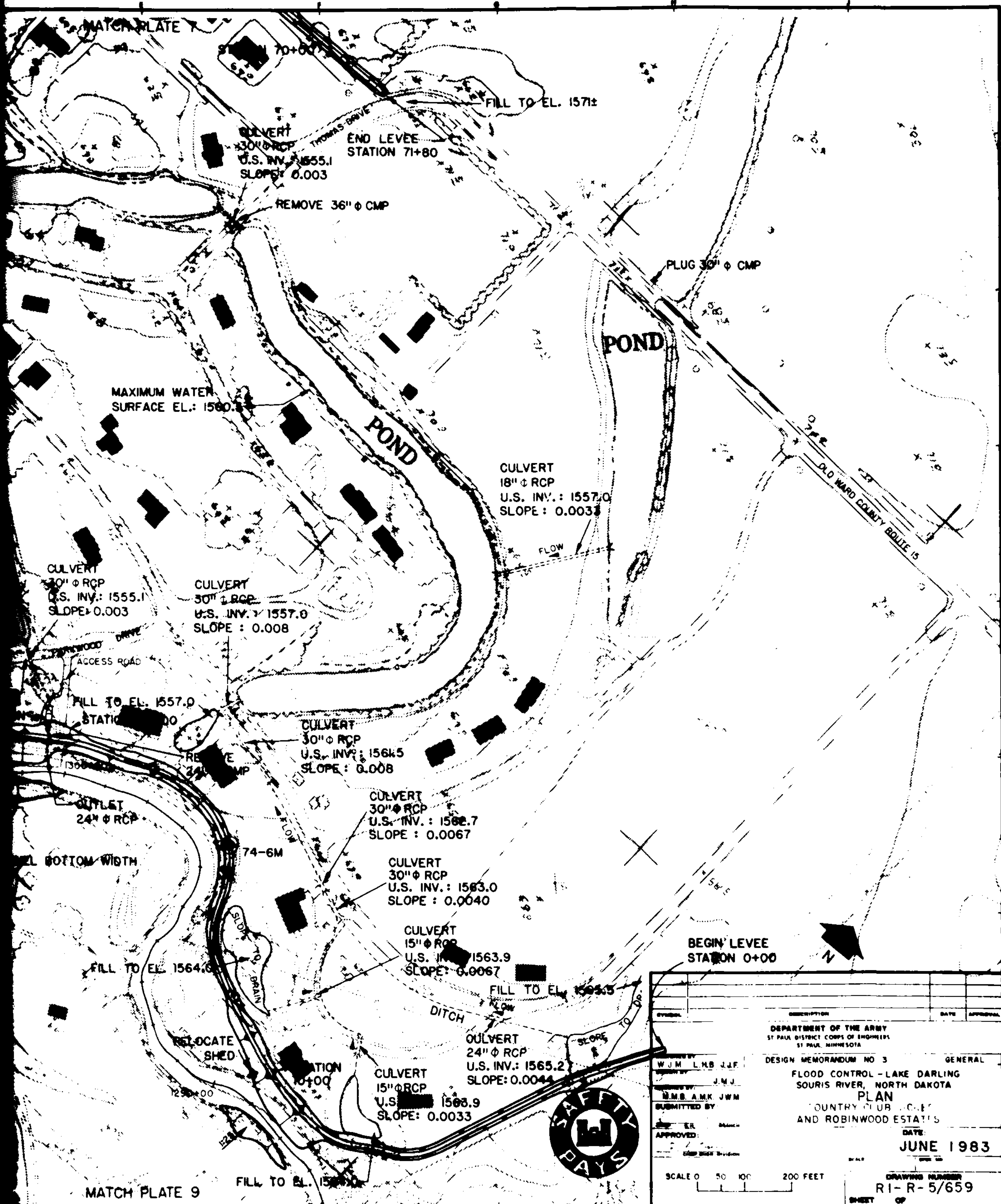
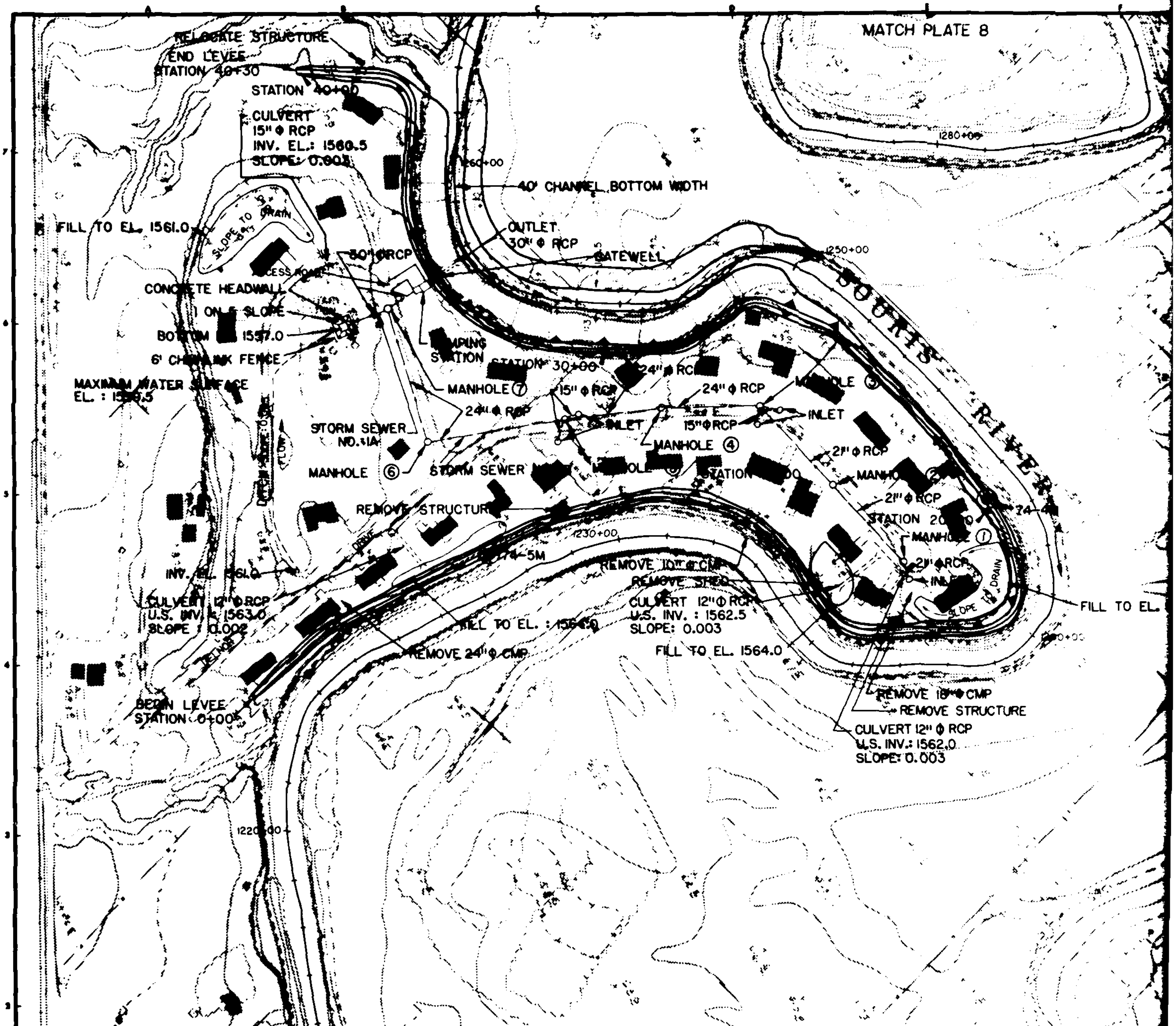


PLATE NO. 29

1 2



MATCH PLATE 8
RELOCATE STRUCTURE
END LEVEE
STATION 40+30
STATION 40+00
CULVERT
15" Φ RCP
INV. EL.: 1560.5
SLOPE: 0.003
40' CHANNEL BOTTOM WIDTH
FILL TO EL. 1561.0
SLOPE TO DRAIN
OUTLET
30" Φ RCP
GATEWELL
30" Φ RCP
CONCRETE HEADWALL
1 ON 6 SLOPE
6' CHAIN LINK FENCE
PUMPING STATION
STATION 30+00
MAXIMUM WATER SURFACE
EL. : 1559.5
MANHOLE ⑦
24" Φ RCP
15" Φ RCP
INLET
24" Φ RCP
15" Φ RCP
INLET
MANHOLE ③
STORM SEWER
NO. 31A
MANHOLE ④
21" Φ RCP
MANHOLE ⑥
MANHOLE
21" Φ RCP
REMOVE STRUCTURE
STATION 20+00
MANHOLE ①
21" Φ RCP
REMOVE 10" Φ CMP
REMOVE SHED
INV. EL. 1561.0
CULVERT 12" Φ RCP
U.S. INV. : 1563.0
SLOPE : 0.002
FILL TO EL. : 1564.0
CULVERT 12" Φ RCP
U.S. INV. : 1562.5
SLOPE: 0.003
FILL TO EL.
FILL TO EL. 1564.0
REMOVE 24" Φ CMP
REMOVE 18" Φ CMP
REMOVE STRUCTURE
BEGIN LEVEE
STATION 0+00
CULVERT 12" Φ RCP
U.S. INV.: 1562.0
SLOPE: 0.003
1280+00
1250+00
1230+00
1220+00
1210+00
1180+00

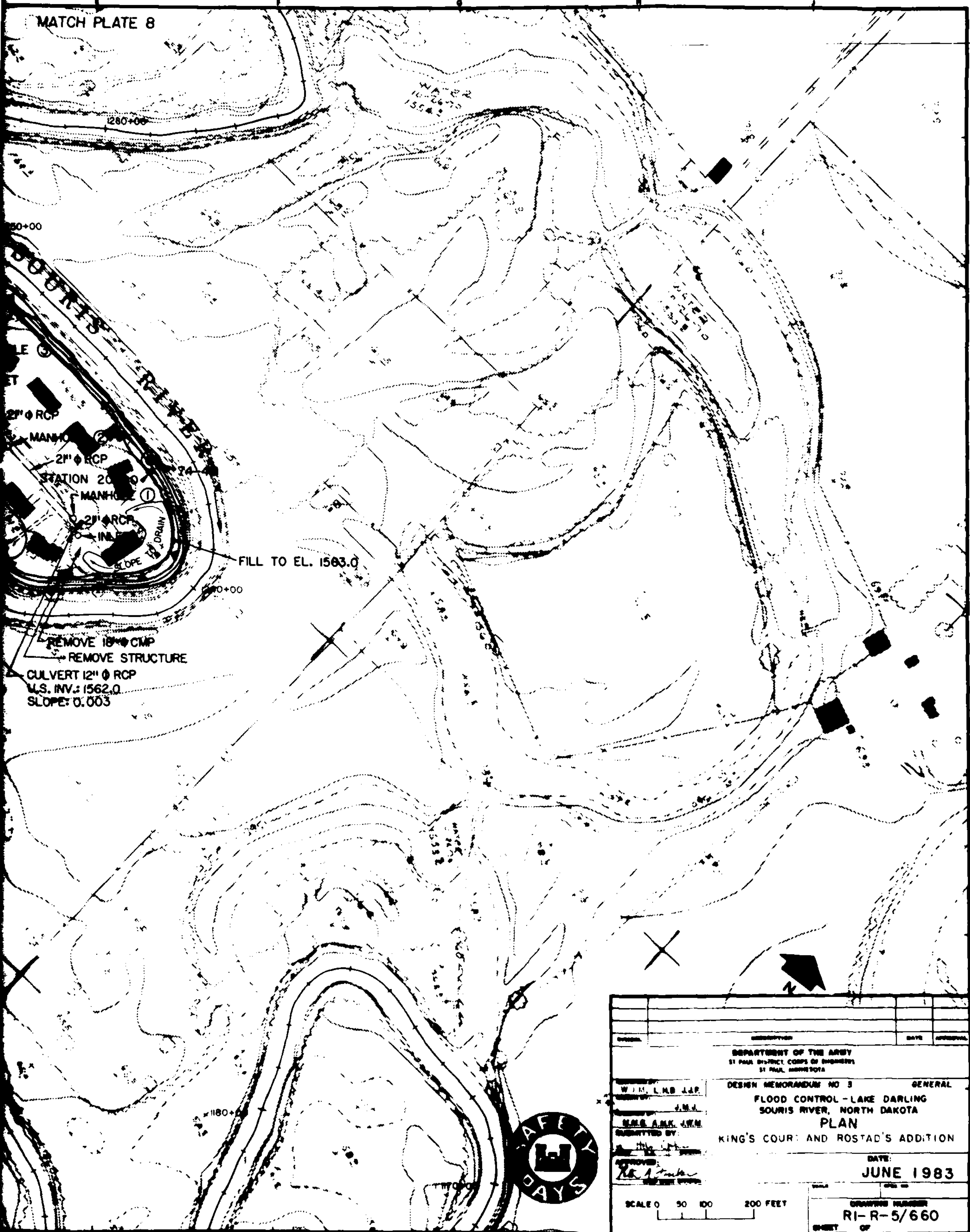
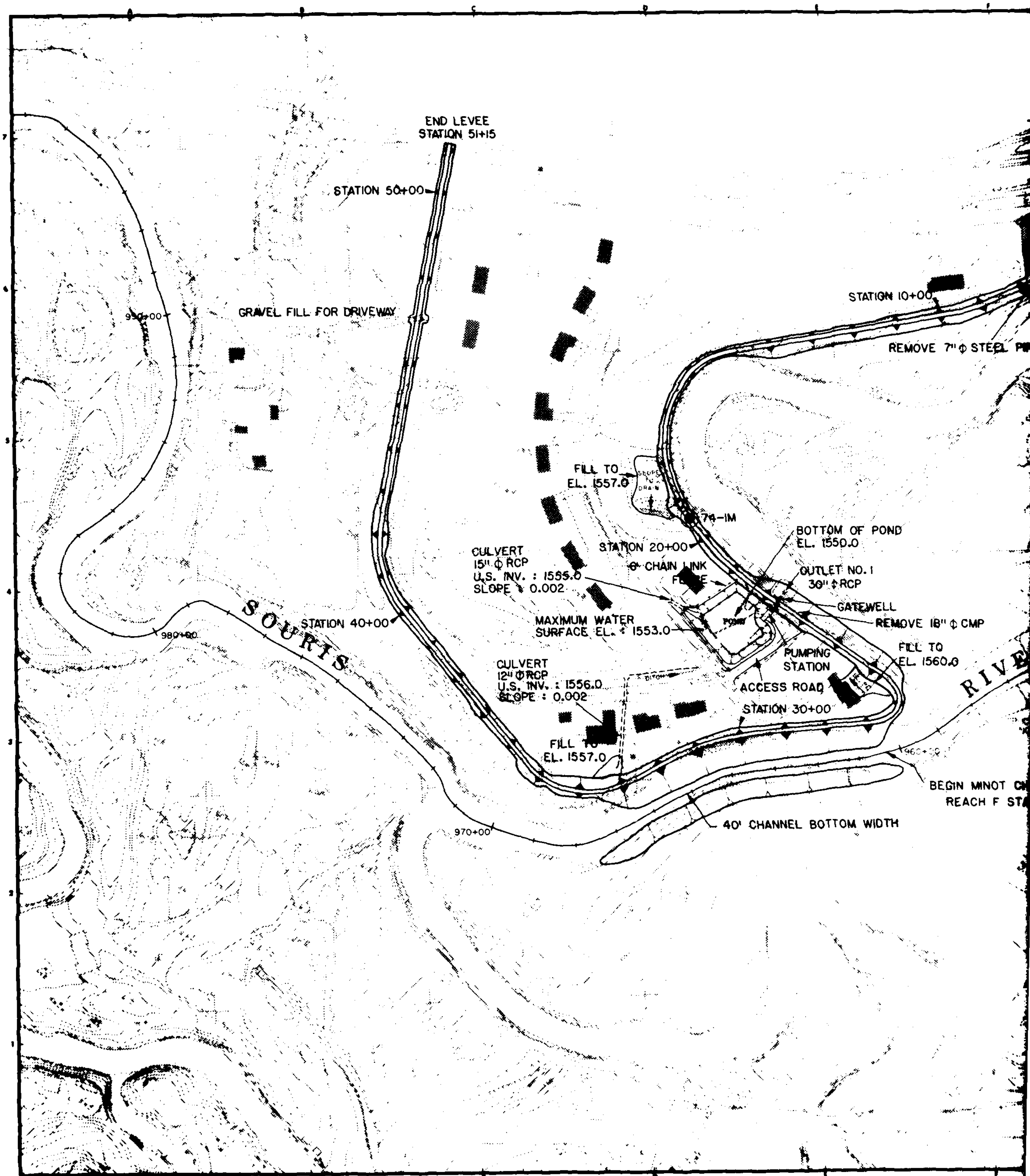


PLATE NO. 30

1 2



END LEVEE
STATION 51+15
STATION 50+00
GRAVEL FILL FOR DRIVEWAY
990+00
STATION 10+00
REMOVE 7" ϕ STEEL
FILL TO
EL. 1557.0
STATION 20+00
BOTTOM OF POND
EL. 1550.0
CULVERT
15" ϕ RCP
U.S. INV. : 1555.0
SLOPE : 0.002
6' CHAIN LINK
FENCE
OUTLET NO. 1
30" ϕ RCP
GATEWELL
SOURIS
STATION 40+00
980+00
MAXIMUM WATER
SURFACE EL. : 1553.0
REMOVE 18" ϕ CMP
POND
PUMPING
STATION
FILL TO
EL. 1560.0
CULVERT
12" ϕ RCP
U.S. INV. : 1556.0
SLOPE : 0.002
ACCESS ROAD
RIVE
STATION 30+00
FILL TO
EL. 1557.0
960+00
BEGIN MINOT
REACH F
970+00
40' CHANNEL BOTTOM WIDTH

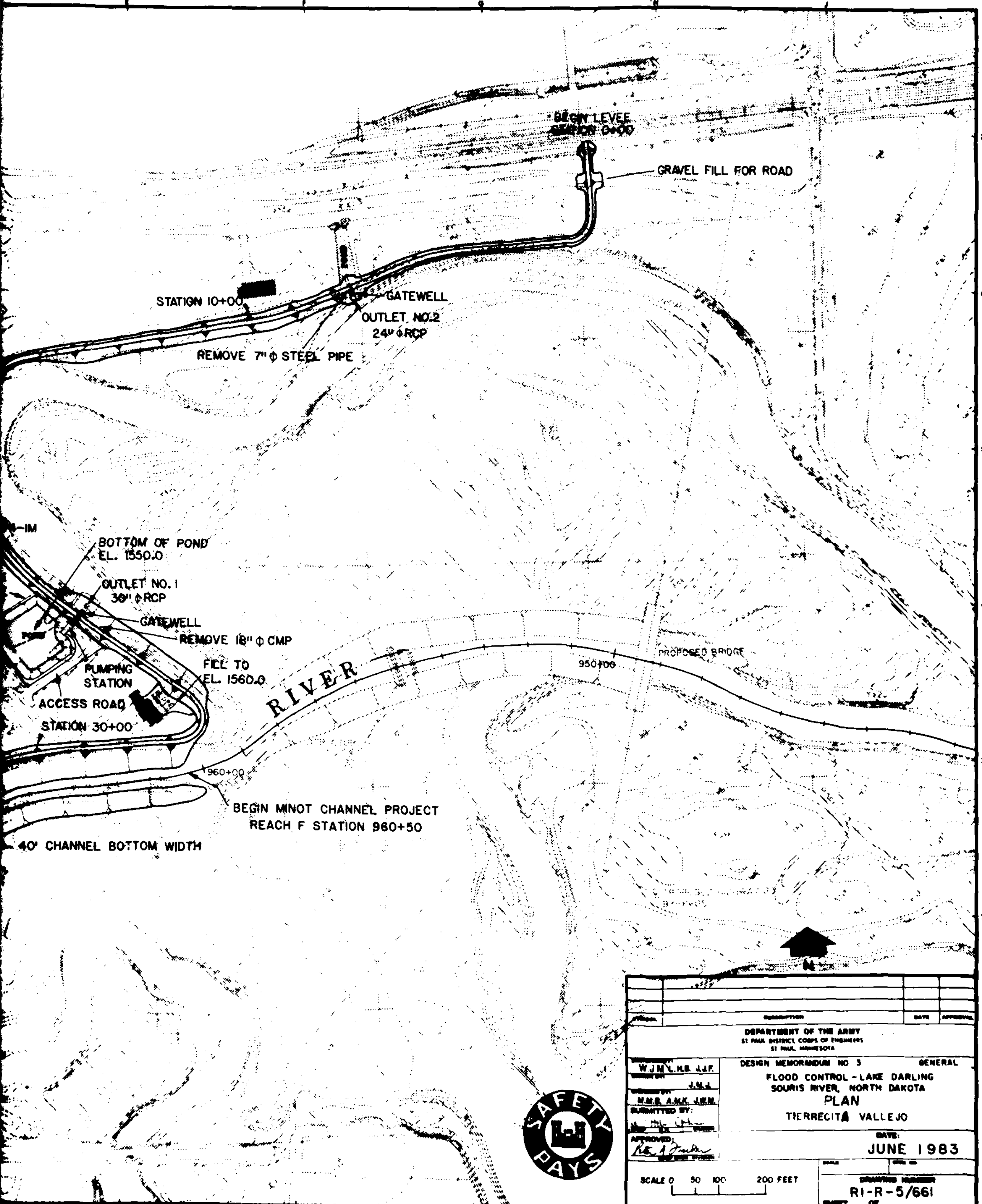
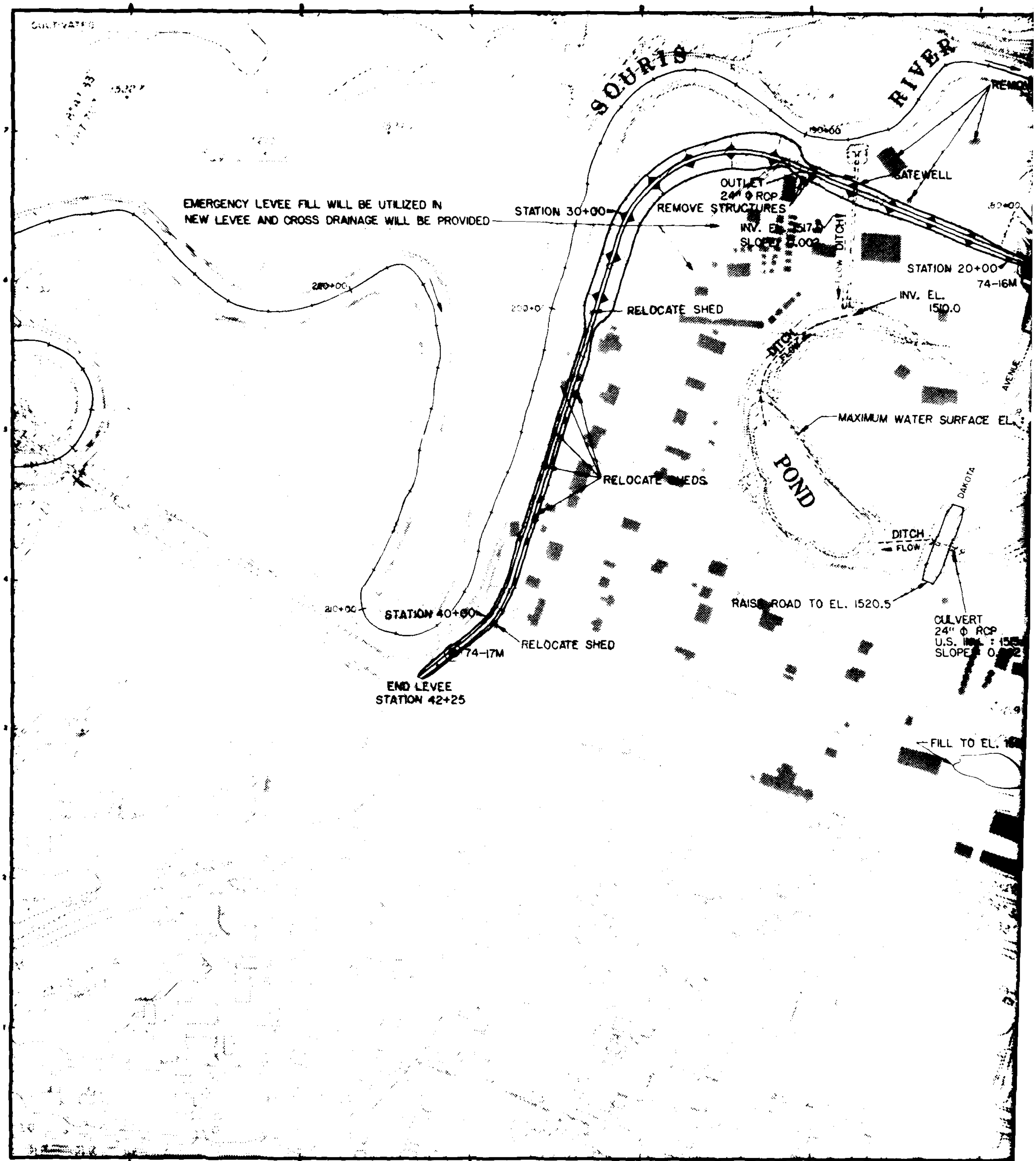


PLATE NO. 31

1 2



SOURIS
RIVER
190+00
GATEWELL
OUTLET
24" Φ RCP
REMOVE STRUCTURES
STATION 30+00
EMERGENCY LEVEE FILL WILL BE UTILIZED IN
NEW LEVEE AND CROSS DRAINAGE WILL BE PROVIDED
STATION 20+00
74-16M
INV. EL.
1510.0
200+00
210+00
RELOCATE SHED
DITCH
FLOW
MAXIMUM WATER SURFACE EL.
RELOCATE SHEDS
POND
DAKOTA
AVENUE
RAISE ROAD TO EL. 1520.5
STATION 40+00
RELOCATE SHED
74-17M
END LEVEE
STATION 42+25
CULVERT
24" Φ RCP
FILL TO EL.

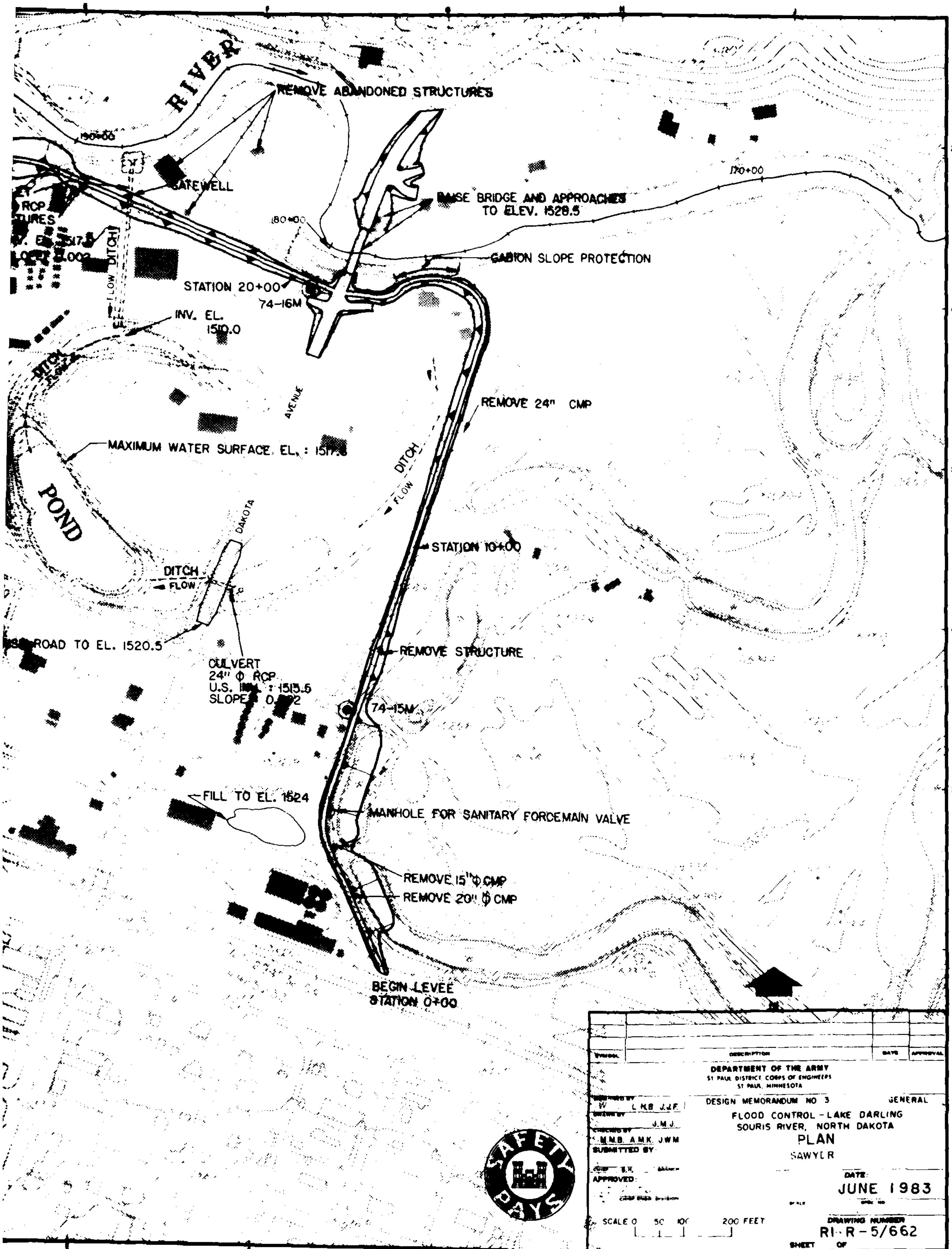
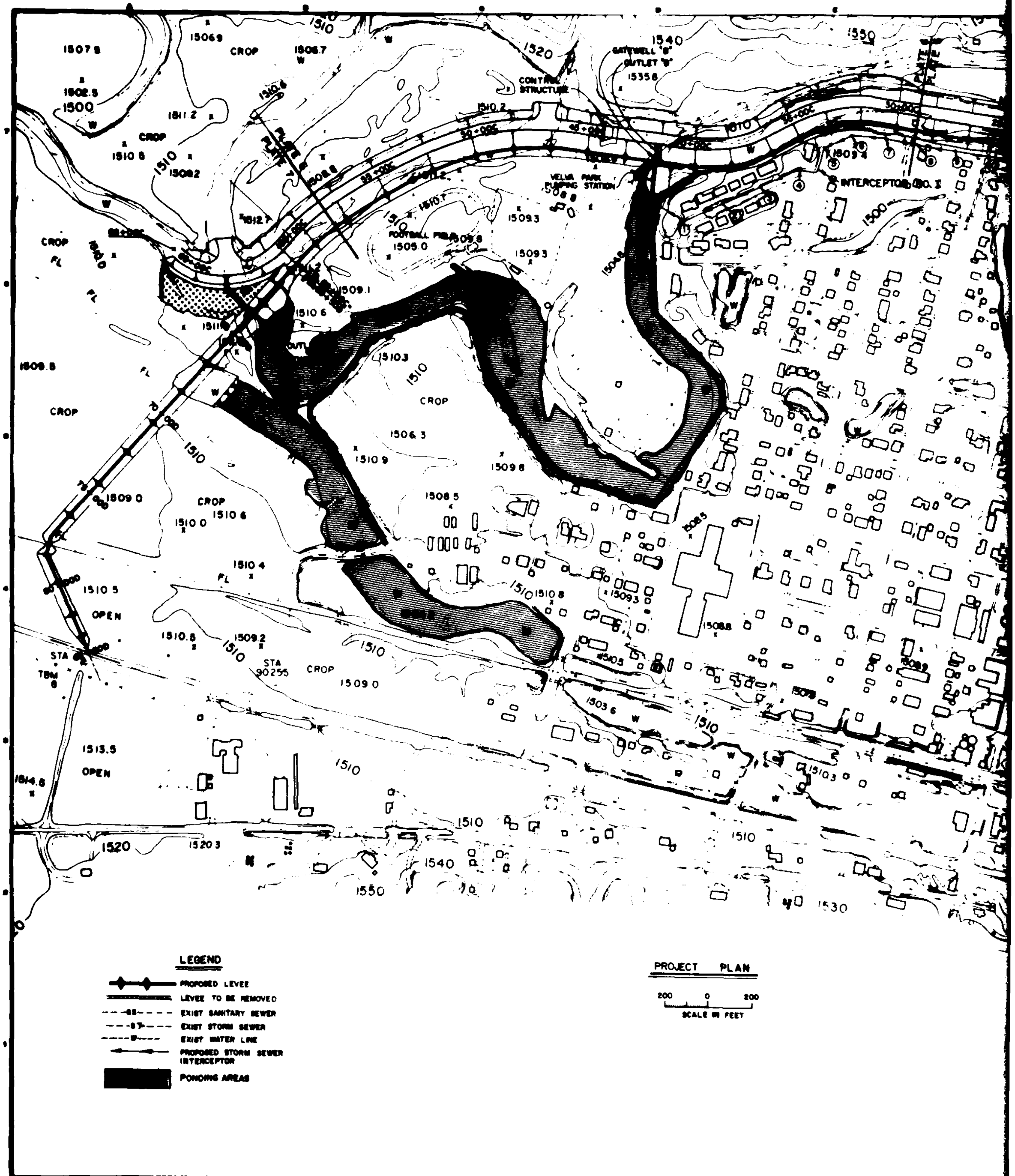

RIVER
REMOVE ABANDONED STRUCTURES
GATEWELL
RAISE BRIDGE AND APPROACHES TO ELEV. 1528.5
170+00
180+00
190+00
GABION SLOPE PROTECTION
STATION 20+00
74-16M
INV. EL. 1510.0
FLOW
DITCH
AVENUE
REMOVE 24" CMP
MAXIMUM WATER SURFACE EL.: 1517.5
POND
DAKOTA
STATION 10+00
ROAD TO EL. 1520.5
REMOVE STRUCTURE
CULVERT
24" Φ RCP
SLOPE
74-15M
FILL TO EL. 1524
MANHOLE FOR SANITARY FORCEMAIN VALVE
REMOVE 15" Φ CMP
REMOVE 20" Φ CMP
BEGIN LEVEE
STATION 0+00
DEPARTMENT OF THE ARMY
ST PAUL DISTRICT CORPS OF ENGINEERS
ST PAUL, MINNESOTA
DESIGN MEMORANDUM NO 3
GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
PLAN
SAWYER
SUBMITTED BY
APPROVED
JUNE 1983
SCALE 0 50 100 200 FEET
DRAWING NUMBER
RI-R-5/662
SAFETY PAYS

PLATE NO. 32



CROP
OPEN
CONTROL STRUCTURE
GATEWELL "B"
OUTLET "B"
VELVA PARK PUMPING STATION
FOOTBALL FIELD
INTERCEPTOR NO. II
STA
TBM
1510
1520
1540
1550
1530
LEGEND
PROPOSED LEVEE
LEVEE TO BE REMOVED
EXIST SANITARY SEWER
EXIST STORM SEWER
EXIST WATER LINE
PROPOSED STORM SEWER INTERCEPTOR
PONDING AREAS
PROJECT PLAN
200 0 200
SCALE IN FEET

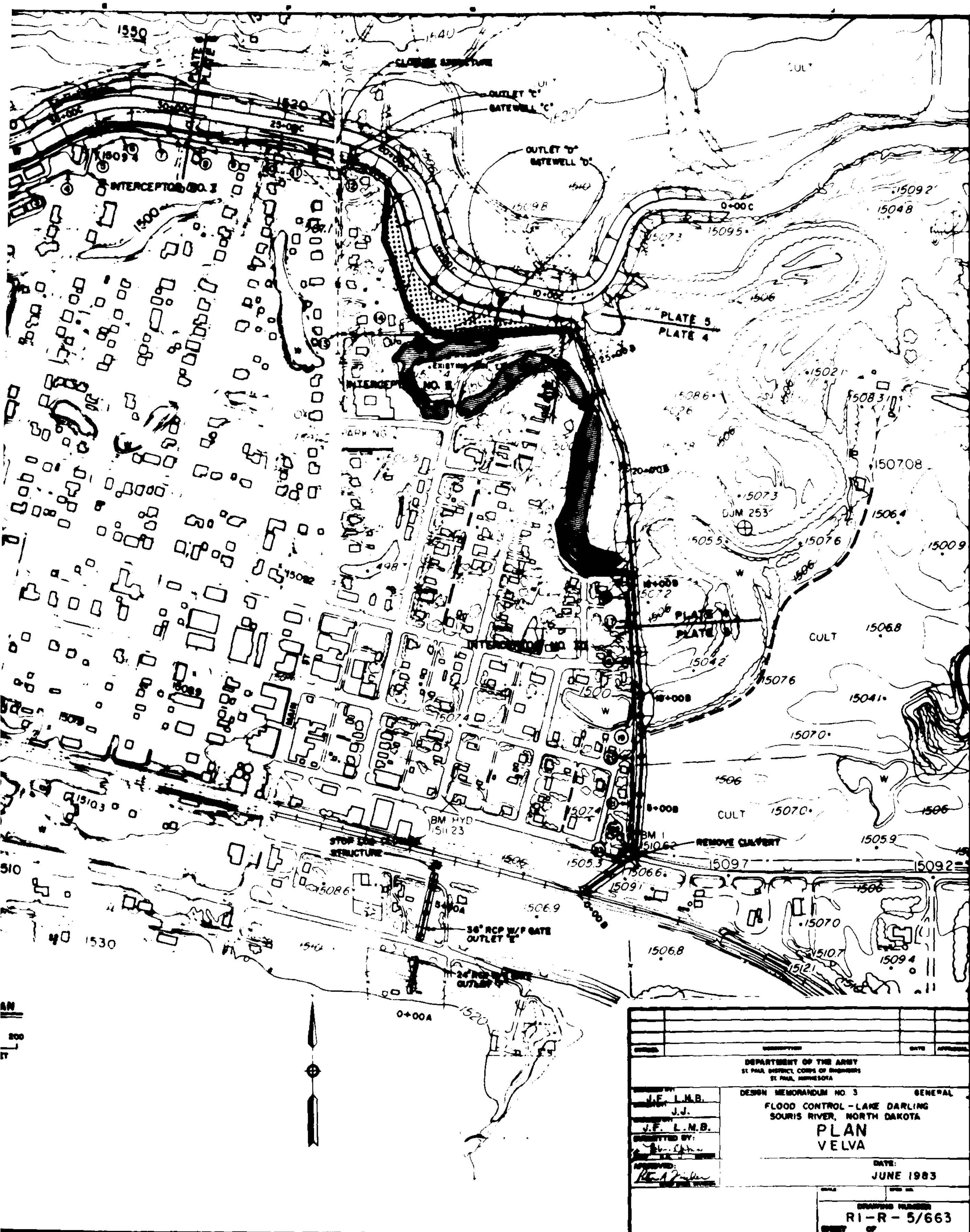
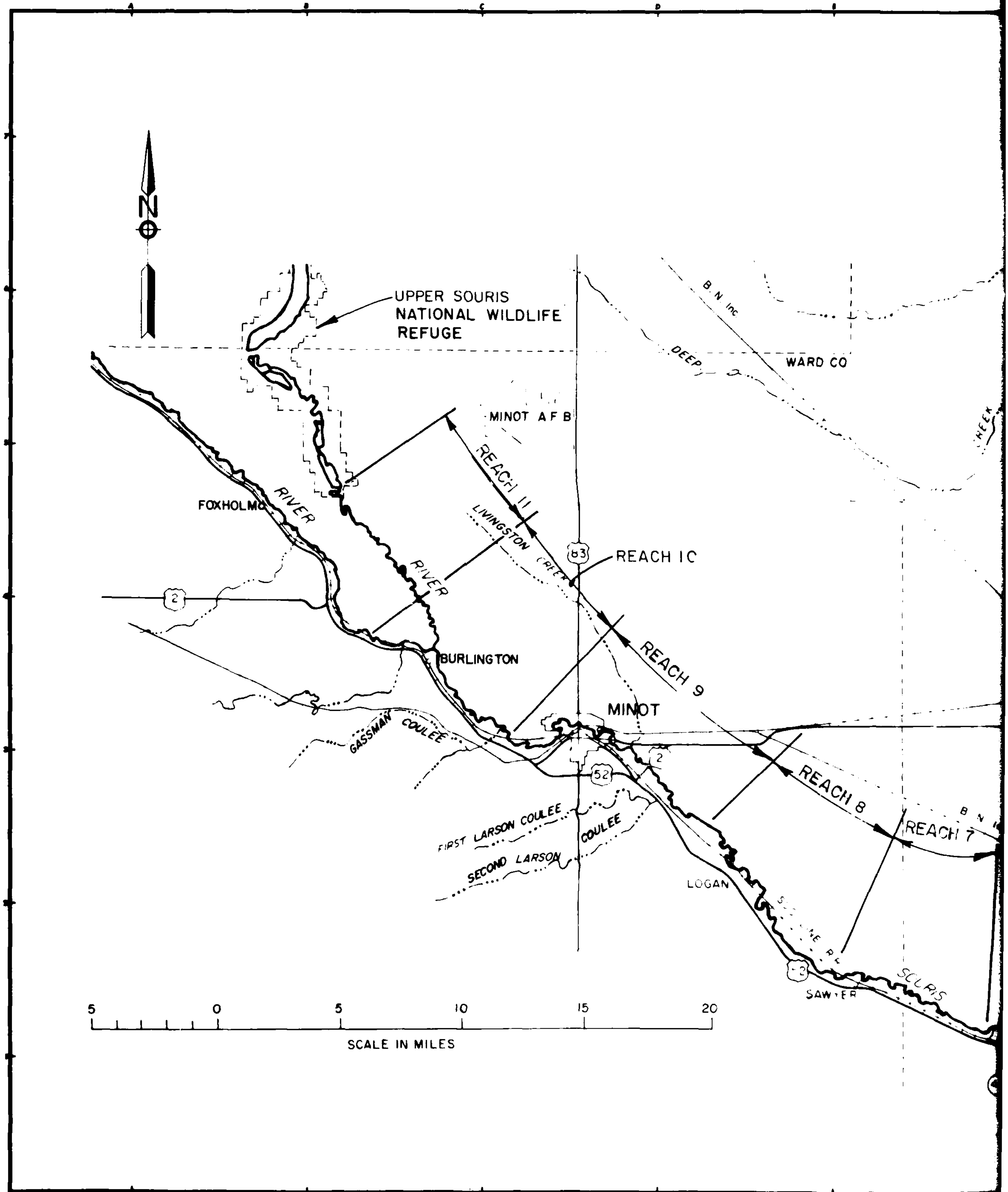
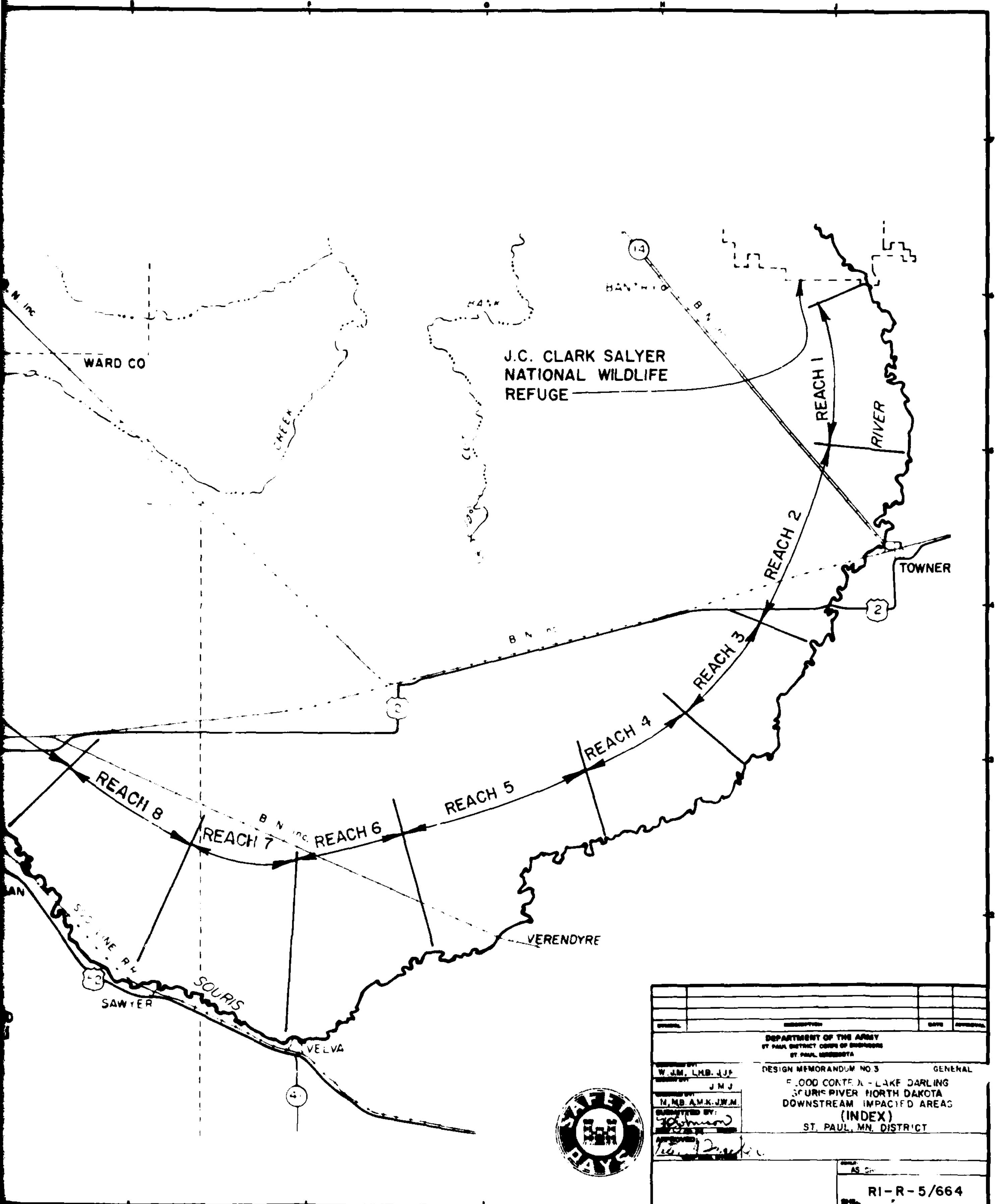

CLOSURE STRUCTURE
OUTLET "C"
GATEWELL "C"
OUTLET "D"
GATEWELL "D"
INTERCEPTOR NO. 1
INTERCEPTOR NO. 2
INTERCEPTOR NO. III
PLATE 5
PLATE 4
CULT
DJM 253
STOP LOG CLOSURE STRUCTURE
BM HYD 1511.23
BM 1 1510.62
REMOVE CULVERT
36" RCP W/F GATE OUTLET "E"
0+00A
DEPARTMENT OF THE ARMY
DESIGN MEMORANDUM NO. 3
GENERAL
J.F. L.M.B.
J.J.
J.F. L.M.B.
SUBMITTED BY:
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
PLAN
VELVA
DATE:
JUNE 1983
RI-R-5/663

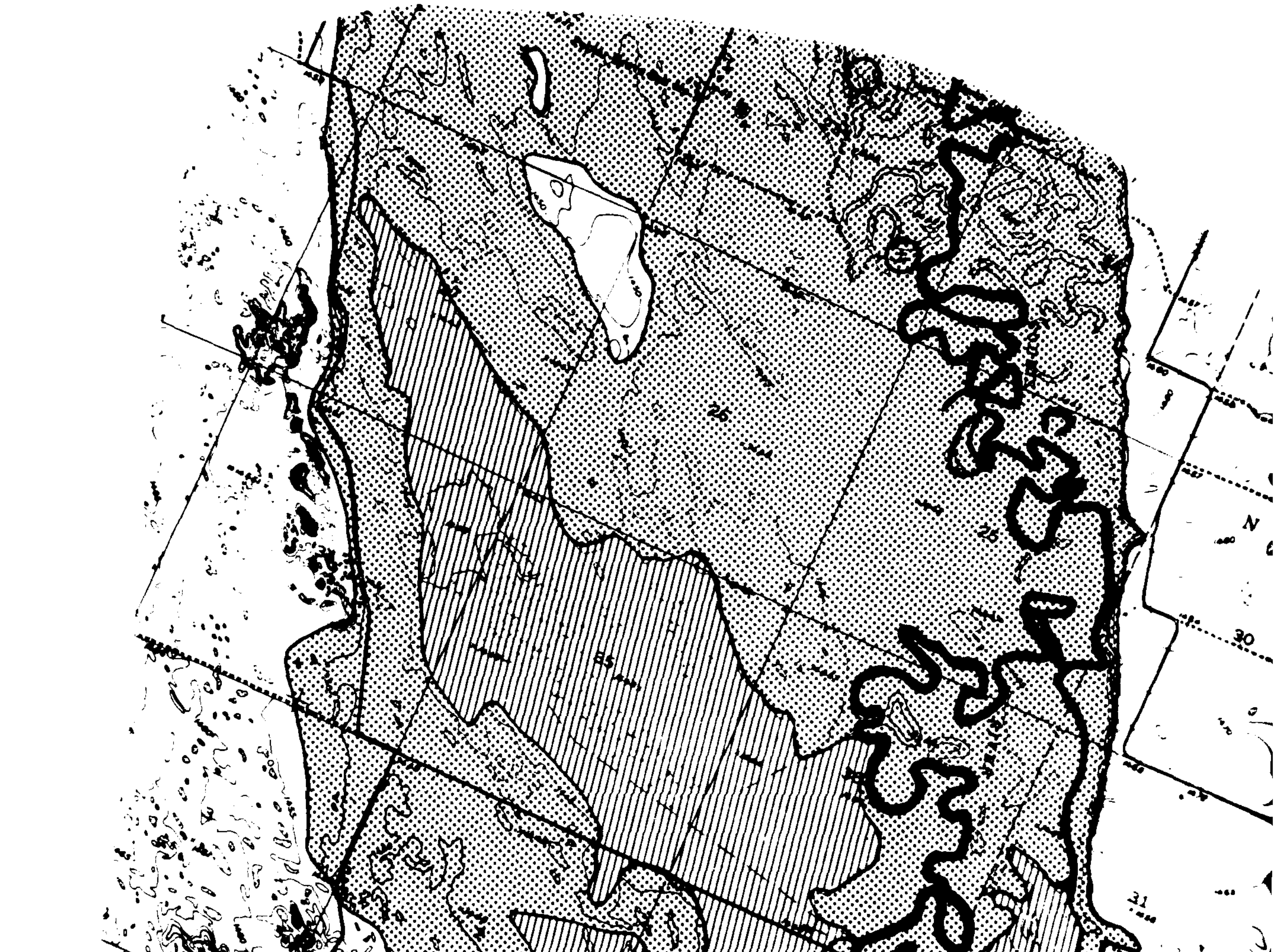
PLATE NO. 33



N
UPPER SOURIS
NATIONAL WILDLIFE
REFUGE
WARD CO
MINOT A F B
REACH 11
REACH 10
REACH 9
REACH 8
REACH 7
LIVINGSTON
FOXHOLM
RIVER
RIVER
BURLINGTON
MINOT
GASSMAN COULEE
FIRST LARSON COULEE
SECOND LARSON COULEE
LOGAN
SAWYER
SOURIS
83
2
52
5 0 5 10 15 20
SCALE IN MILES


J.C. CLARK SALYER
NATIONAL WILDLIFE
REFUGE
WARD CO
REACH 1
REACH 2
REACH 3
REACH 4
REACH 5
REACH 6
REACH 7
REACH 8
RIVER
SOURIS
TOWNER
VERENDYRE
SAWYER
VELVA
B N RR
14
2
DEPARTMENT OF THE ARMY
DESIGN MEMORANDUM NO 3
GENERAL
W. J.M., L.H.B. J.J.F
J M J
M. M.B. A.M.K. J.W.M.
SUBMITTED BY:
APPROVED:
DOWNSTREAM IMPACTED AREAS
(INDEX)
ST. PAUL, MN. DISTRICT
AS SH
RI-R-5/664
SAFETY PAYS
PLATE NO. 34

2



LEGEND

AREA AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

AREA AFFECTED BY 500 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

DWELLINGS AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

0 2000 4000

SCALE IN FEET

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P.
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY: Stan Kumpula
APPROVED: Peter A. Fischer

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

DOWNSTREAM IMPACTED AREA

REACH I

ST. PAUL, MN. DISTRICT

DATE: JUNE 1983

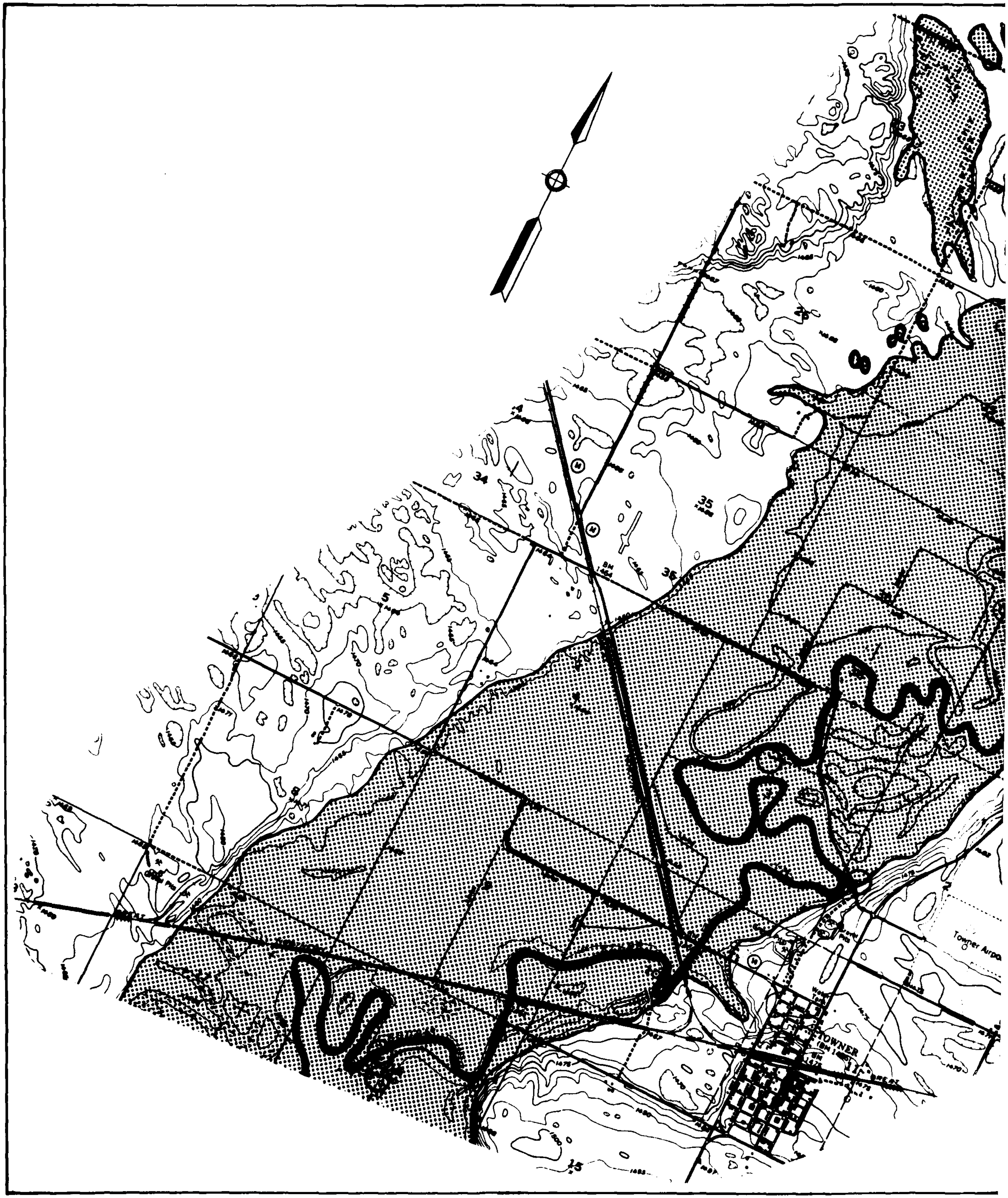
SCALE | SPEC. NO.

DRAWING NUMBER RI-R-5/665

SHEET OF

PLATE NO. 35

1 2


TOWNER

LEGEND

AREA AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

DWELLINGS AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

0 2000 4000

SCALE IN FEET

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P.
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY: Stan Kumpula
APPROVED: Peter A. Fischer

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
DOWNSTREAM IMPACTED AREA
REACH 2
ST. PAUL, MN. DISTRICT

DATE: JUNE 1983

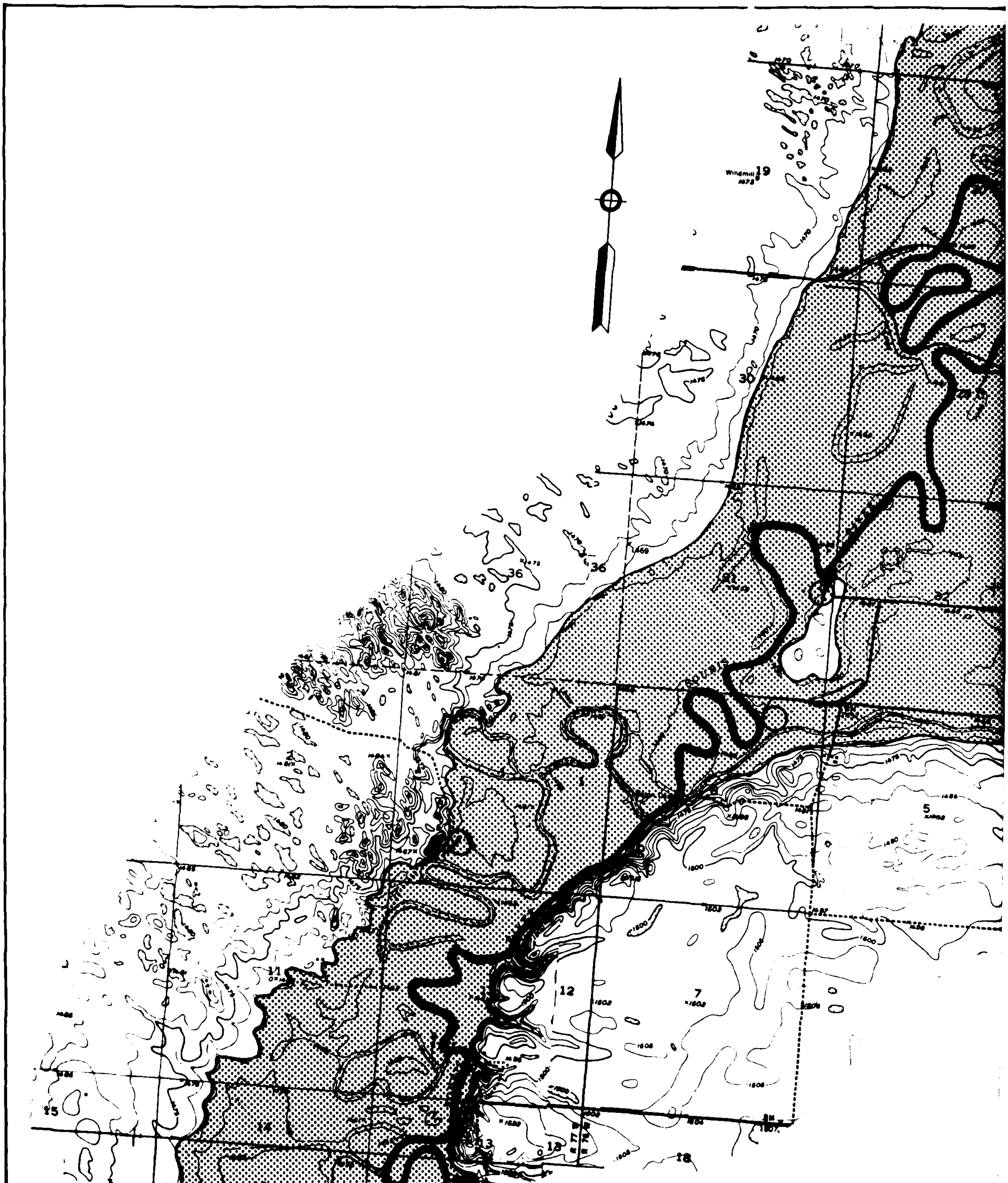
SCALE: SPEC. NO.

DRAWING NUMBER
RI-R-5/666

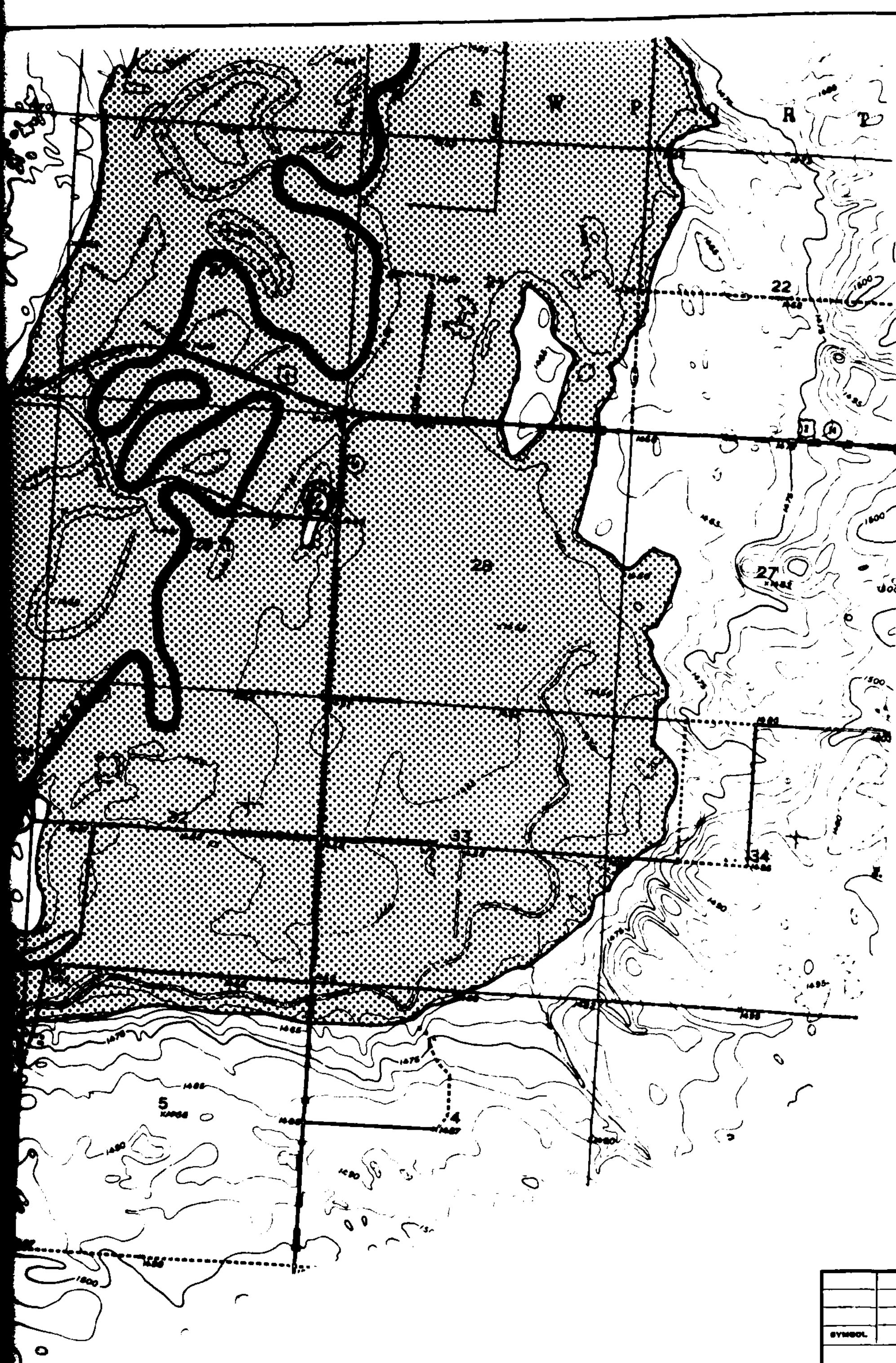
SHEET OF

PLATE NO. 36

1 2



Windmill 19
30
36
36
5
7
12
11
14
15
13
13
18



LEGEND

AREA AFFECTED BY 5,[illegible] RESERVOIR RELEASES PLUS LOCAL INFLOW

DWELLINGS AFFECTED BY 5,[illegible] CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

0 2000 4000

SCALE IN FEET

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P.
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY: Stan Kumpula
APPROVED: Peter A. Fischer

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

DOWNSTREAM IMPACTED AREA

REACH 3

ST PAUL, MN. DISTRICT

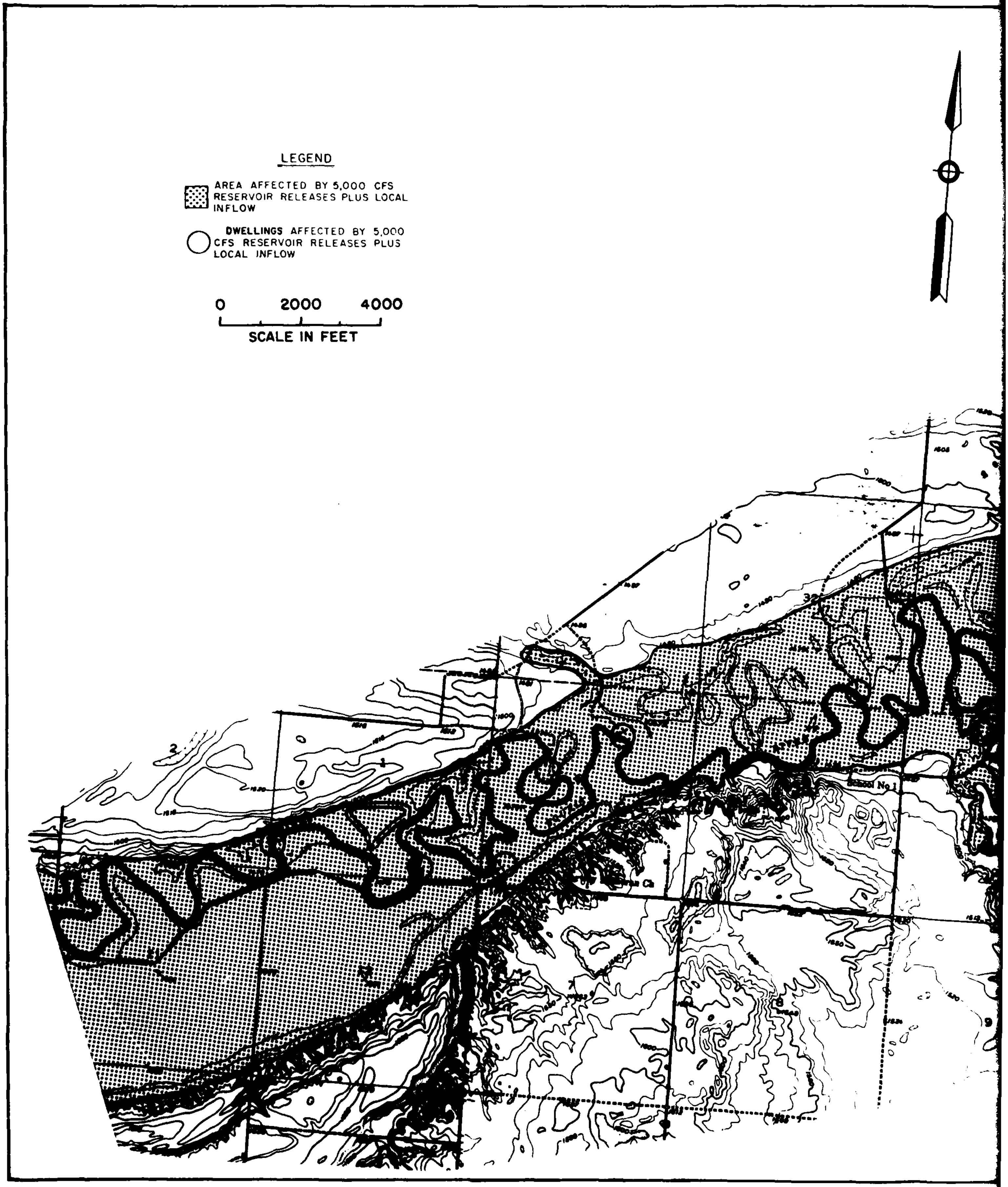
DATE: JUNE 1983

DRAWING NUMBER
RI-R-5/667

SHEET OF

PLATE NO. 37

1 7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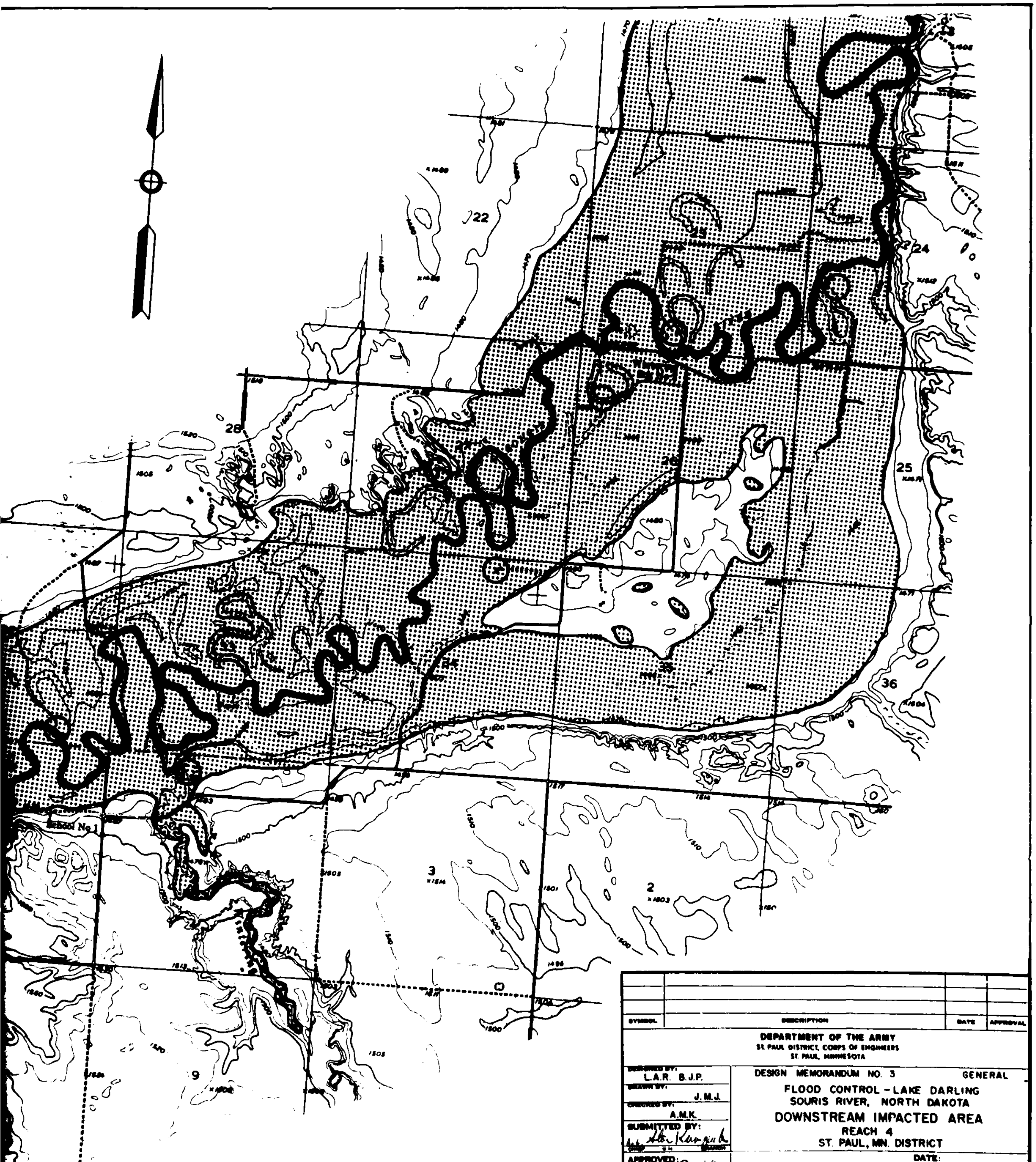
AREA AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW
DWELLINGS AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW
0 2000 4000
SCALE IN FEET
School No 1



SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P.
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY: [signature]
APPROVED: [signature]

DESIGN MEMORANDUM NO. 3 GENERAL

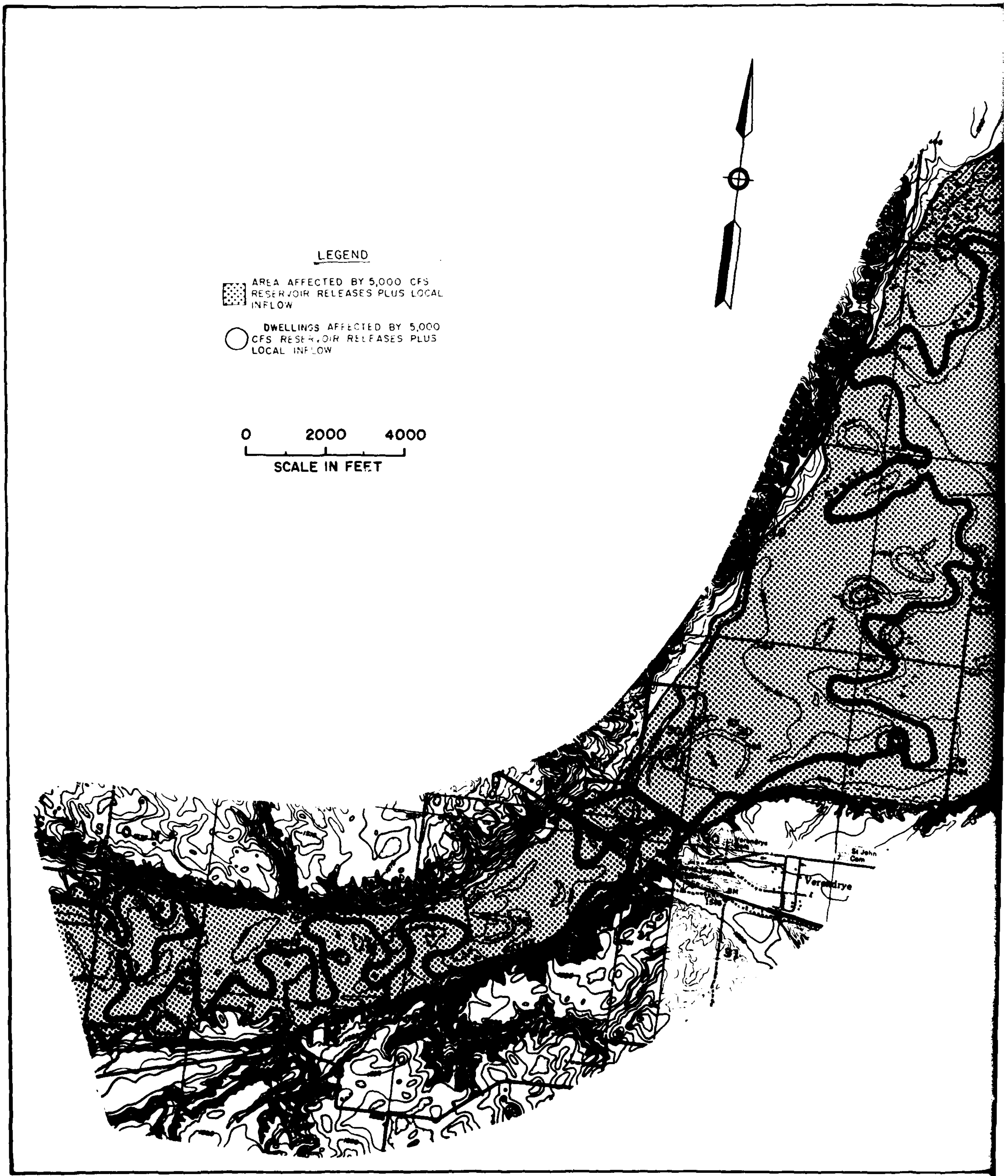
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
DOWNSTREAM IMPACTED AREA
REACH 4
ST. PAUL, MN. DISTRICT

DATE: JUNE 1983

SCALE:
SPEC. NO.
DRAWING NUMBER
RI-R-5/668
SHEET OF

PLATE NO. 38

2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AREA AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW
DWELLINGS AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW
0 2000 4000
SCALE IN FEET
Verendrye

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P.
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY: [signature]
APPROVED: [signature]

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
DOWNSTREAM IMPACTED AREA
REACH 5
ST. PAUL, MN. DISTRICT

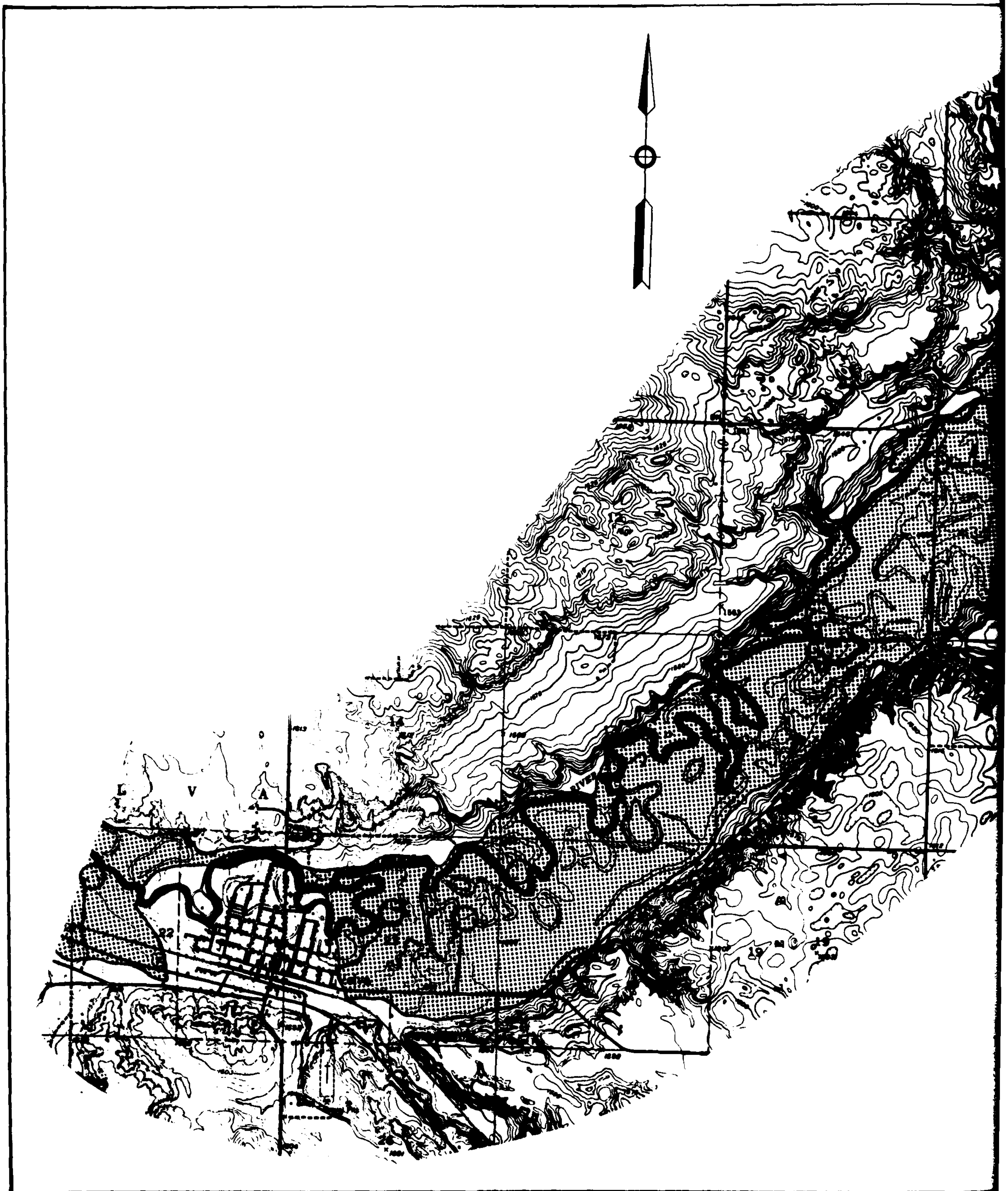
DATE: JUNE 1983

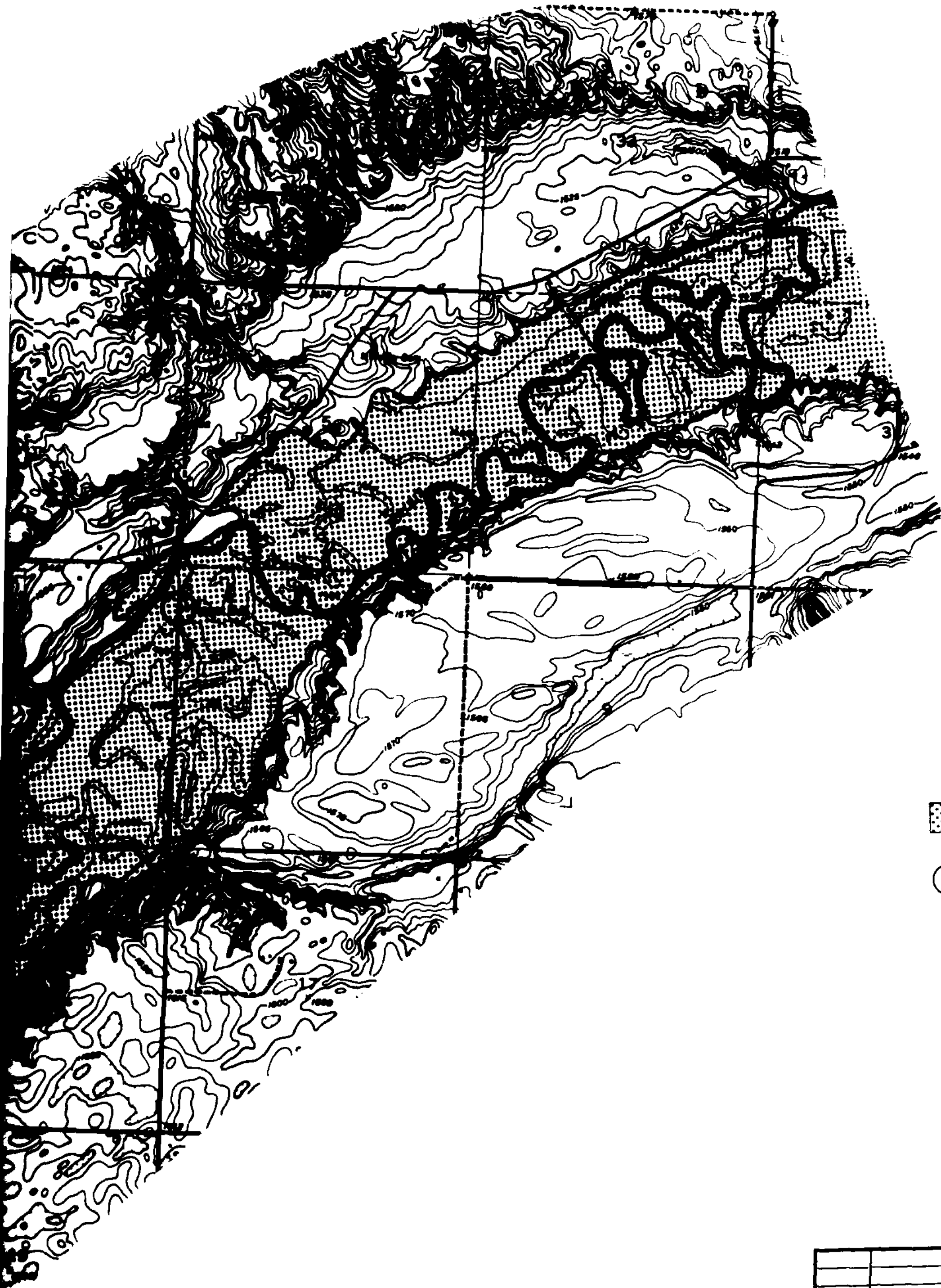
SCALE | SPEC. NO.

DRAWING NUMBER
R1-R-5/699
SHEET OF

PLATE NO. 39

1 2





LEGEND

AREA AFFECTED BY 5,[illegible] CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

DWELLINGS AFFECTED BY 5,[illegible] CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

0 2000 4000

SCALE IN FEET

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P.
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY: Stan Kumpula
APPROVED: Peter A. Fischer

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
DOWNSTREAM IMPACTED AREA
REACH 6
ST. PAUL, MN. DISTRICT

DATE: JUNE 1983

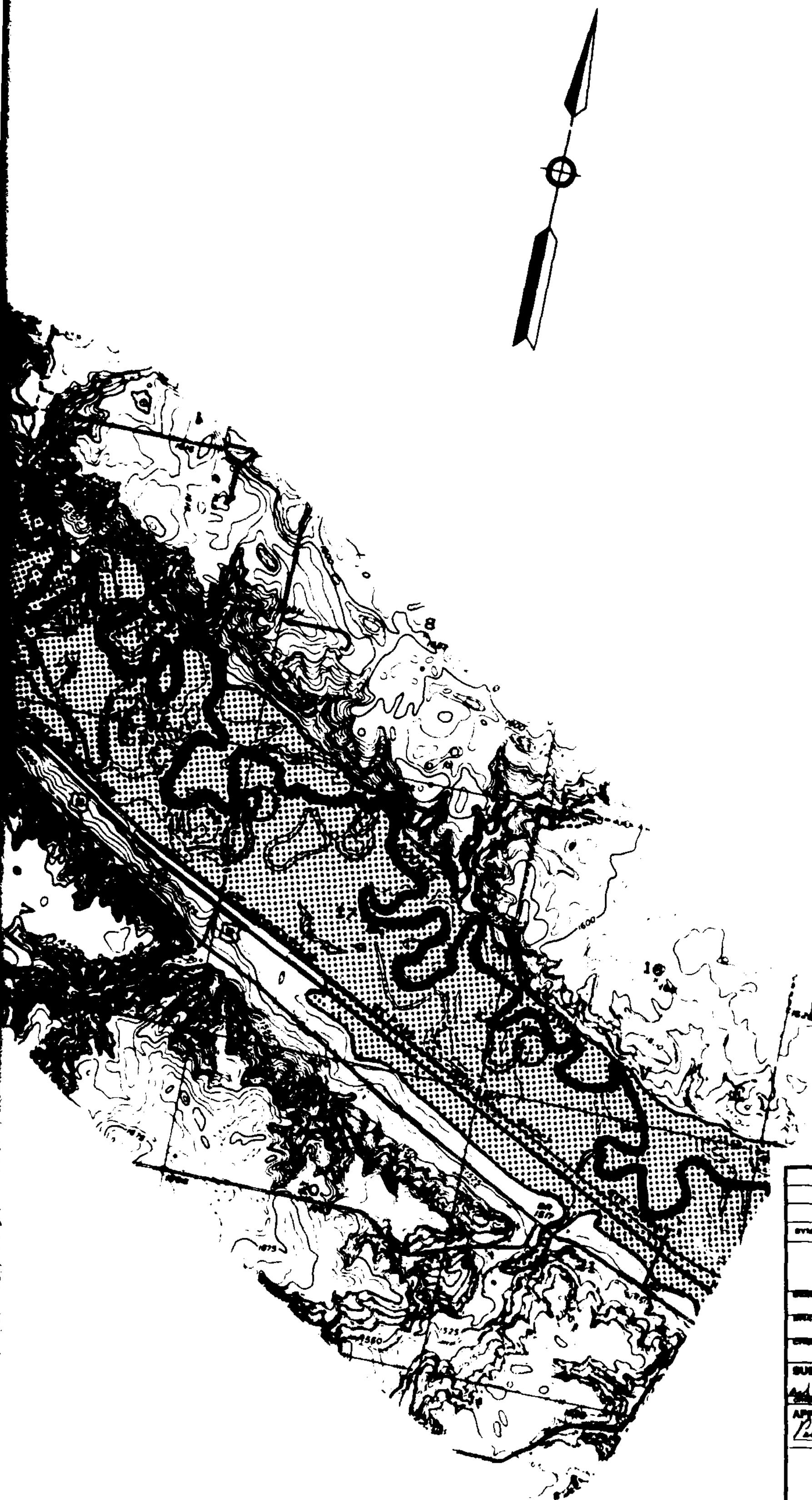
SCALE | SPEC. NO.

DRAWING NUMBER R1-R-5/670

SHEET OF

1 2

PLATE NO. 40



LEGEND

AREA AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

DWELLINGS AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

0 2000 4000

SCALE IN FEET

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P.
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY:
APPROVED:

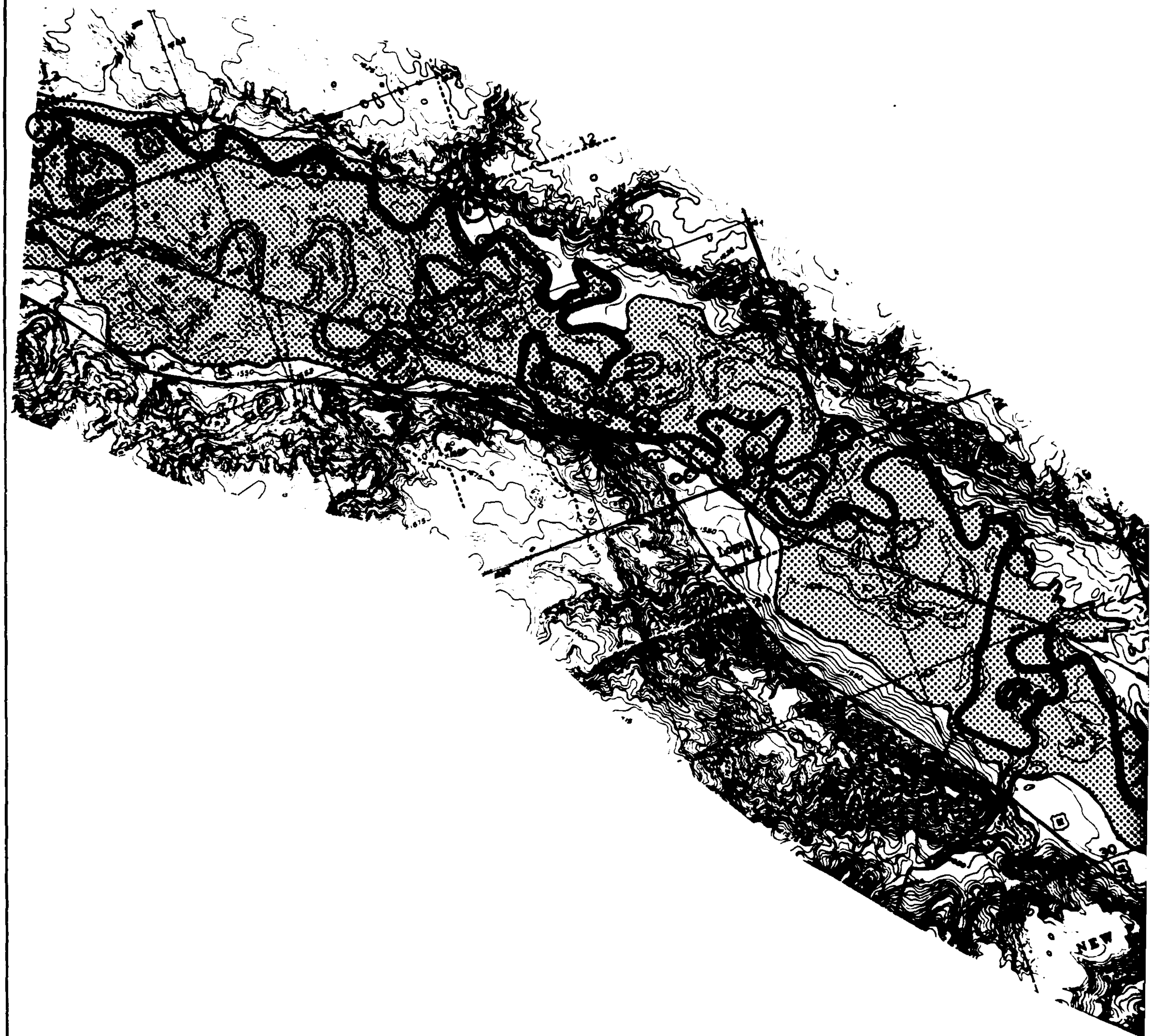
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
DOWNSTREAM IMPACTED AREA
REACH 7
ST. PAUL, MN. DISTRICT

DATE: JUNE 1983

DRAWING NUMBER
RI-R-5/671
SHEET OF

PLATE NO. 41

2



LEGEND

AREA AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

DWELLINGS AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

0 2000 4000

SCALE IN FEET

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P.
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY:
APPROVED:

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

DOWNSTREAM IMPACTED AREA
REACH 8
ST. PAUL, MN. DISTRICT

DATE: JUNE 1983

SCALE: SPEC. NO.

DRAWING NUMBER
R1-R-5/672
SHEET OF

PLATE NO. 42

1 2

LEGEND

AREA AFFECTED BY 5,C
RESERVOIR RELEASES P
INFLOW

DWELLINGS AFFECTED
CFS RESERVOIR RELEA
LOCAL INFLOW

LEGEND

AREA AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

DWELLINGS AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P.
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY: /s/ Stan Kumpula
APPROVED: Peter A. Fischer

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
DOWNSTREAM IMPACTED AREA
REACH 9
ST. PAUL, MN. DISTRICT

DATE: JUNE 1983

SCALE

DRAWING NUMBER
RI-R-5/673
SHEET OF

PLATE NO. 43

LEGEND

AREA AFFECTED ... CF
RESERVOIR RELEASE ... LO
INFLOW

DWELLINGS AFFECTED BY 5,(
CFS RESERVOIR RELEASE PL
LOCAL INFLOW

LEGEND

AREA AFFECTED BY 5,000 CFS RESERVOIR RELEASE PLUS LOCAL INFLOW

DWELLINGS AFFECTED BY 5,000 CFS RESERVOIR RELEASE PLUS LOCAL INFLOW

0 2000 4000
SCALE IN FEET

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY: Stan Kumpula
APPROVED: Peter A. Buckley

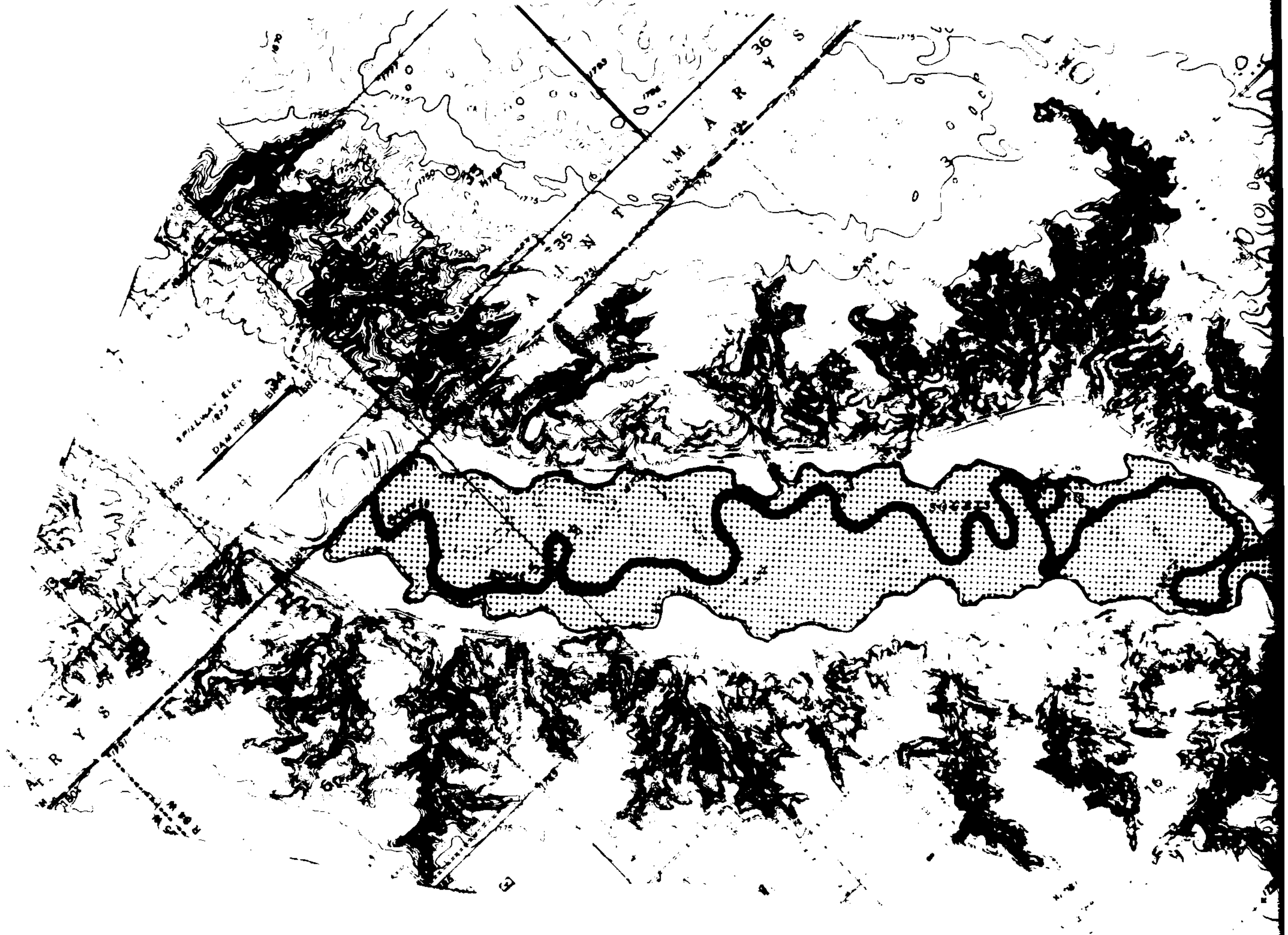
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
DOWNSTREAM IMPACTED AREA
REACH 10
ST. PAUL, MN. DISTRICT

DATE: JUNE 1983

SCALE
SPEC. NO.
DRAWING NUMBER
RI-R-5/674
SHEET OF

PLATE NO. 44

1 2



LEGEND

AREA AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

DWELLINGS AFFECTED BY 5,000 CFS RESERVOIR RELEASES PLUS LOCAL INFLOW

2000 0 2000 4000

SCALE IN FEET

LEGEND

TED BY 5,000 CFS
RELEASES PLUS LOCAL

AFFECTED BY 5,000
OIR RELEASES PLUS
W

2000 4000

FEET

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.A.R. B.J.P.
DRAWN BY: J.M.J.
CHECKED BY: A.M.K.
SUBMITTED BY:
APPROVED:

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

DOWNSTREAM IMPACTED AREA
REACH II

ST. PAUL, MN. DISTRICT

DATE: JUNE 1983

DRAWING NUMBER
RI - R - 5/ 675
SHEET OF

PLATE NO. 45

FLOOD CONTROL
LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

DESIGN MEMORANDUM NO. 3
GENERAL PROJECT DESIGN

APPENDIX A

HYDROLOGY AND HYDRAULICS

DEPARTMENT OF THE ARMY
St. Paul District Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101

FLOOD CONTROL - LAKE DARLING

SOURIS RIVER, NORTH DAKOTA

DESIGN MEMORANDUM NO. 3 - GENERAL

PROJECT DESIGN

APPENDIX A

HYDROLOGY AND HYDRAULICS

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TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLES

TABLES (Cont.)

TABLES (Cont.)

FIGURES

PLATES

PLATES (Cont.)

PLATES (Cont.)

HYDROLOGY

HYDROLOGY

1. LOCATION AND STREAMS

The Souris River basin lies in the southeastern portion of Saskatchewan and the southwestern portion of Manitoba, both in Canada, and in the northwestern part of North Dakota and the northeastern tip of Montana within the United States, as shown on plate A-1. The basin includes a total surface area of about 24,800 square miles. Of this, 15,480 square miles, or 62.4 percent, are in Canada and 9,320 square miles, or 37.6 percent, are in the United States. All of the basin within the United States, except for about 30 square miles in northeastern Montana, lies within North Dakota. Drainage areas above the upper and lower Souris River crossings of the international boundary are 8,630 and 16,900 square miles, respectively. Above Minot (mile 388.5) the Souris River drains an area of 10,600 square miles. A map of the basin is shown on plate A-2.

2. The Souris River rises in the vicinity of Weyburn, Saskatchewan, and flows in a southeasterly direction for about 217 miles where it enters the United States midway between Northgate and Sherwood in northwestern North Dakota. It continues on a southeasterly course through Renville and Ward Counties. At Velva, in McHenry County, the river swings northeast to Towner and forms a loop in the United States as it gradually assumes a northwesterly direction through Bottineau County from where it flows back into Canada. In Canada, it empties into the Assiniboine River, which flows into the Red River of the North at Winnipeg, Manitoba. The stream has a total length of about 729 miles, including about 358 miles in North Dakota. Major tributaries within the United States are the Des Lacs (mile 395.4). Wintering (mile 283.3), and Deep Rivers (mile 180.8) and Willow Creek (mile 210.1) which have total drainage areas of 1,051, 717, 1,735, and 1,764 square miles, respectively. In Canada the major tributaries of the Souris River include Long Creek (mile 621.5), Moose Mountain Creek (mile 549.9), and Antler River (mile 142.8), with total drainage areas of 2,678, 2,312, and 1,346 square miles, respectively. Other important tributaries include Roughbark, Short, Gainsborough, Graham, Jackson, and Plum Creeks which join the Souris River in Canada and Livingston, Stone and Boundary Creeks, Bonnes Coulee, and Gassman Coulee in the United States.

3. TOPOGRAPHY

There are three distinct types of topography which characterize the Souris River basin: the hilly Max moraine in the southwest part of the basin; the gently rolling ground moraine plain composing the central part of the area; and the nearly flat featureless area to the east, once inundated by glacial Lake Souris. The highest point in the basin, about elevation 2500, occurs in Burke County west of the Des Lacs River; and the

lowest point, about elevation 1410, occurs in the Souris River Valley at the international boundary in Bottineau County. Thus, the maximum relief within the United States portion of the basin is about 1,090 feet.

4. The Max moraine, a strip of numerous hills and undrained depressions about 15 to 20 miles wide, trends southeastward from Canada across the international boundary at the North Dakota-Montana border and generally follows the southwesterly boundary of the Souris River basin until it merges gradually into the ground moraine plain south of Verendrye. The ground moraine plain has gently rolling topography characterized by many undrained, saucer-shaped depressions and, to a lesser degree, small mounds and ridges. The primary modifying features of this plain are the valleys of the Souris and Des Lacs Rivers and their steep-walled tributaries. The valley width varies from one-half mile where the Souris River enters the United States, to about 1 mile at Minot, and averages about three-fourths of a mile. The valley depth varies from 100 to 225 feet.

5. Other modifying features include glacial outwash channels 5 to 30 feet deep, which usually trend normal to the regional slope toward the north-east; glacial diversion channels; and several types of ice-contact features. The ice-contact features include numerous conical hills and irregular ridges and peculiar linear ridges in the southeastern part of the area. Near the northeast escarpment of the Max moraine the plain slopes generally 50 to 80 feet per miles. However, this slope decreases to about 40 feet per mile near the Souris and Des Lacs Rivers and to 20 feet or less per mile northeast of these streams.

6. The glacial Lake Souris area is nearly flat and featureless except for some sand dunes up to 50 feet high and numerous depressions which often contain lakes. Through this area the Souris River flows sluggishly in a channel less than 100 feet lower than the surrounding terrain and, in much of its course through the glacial Lake Souris area, the river is not entrenched. Just northeast of this glacial lake bed near the eastern boundary of the basin, the rugged hills of the Turtle Mountain rise along the international boundary.

7. Much of the drainage pattern within the Souris River basin varies from poorly defined to noncontributing, except at the northeast excarpment of the Max moraine and near the stream valleys. Many of the noncontributing areas include numerous small but easily distinguished depressions where trapped surface waters pond. However, in a 200-square-mile upland region between the Souris and Des Lacs Rivers, the land drains generally toward a 20-square-mile depressed area near Tolley, North Dakota, which has no outlet.

8. EXISTING RESERVOIRS

Excluding small low-head dams, there are approximately 22 dams located on the Souris River. Within the United States portion of the river there are 13 dams operated by the U.S. Fish and Wildlife Service and one irrigation dam, Eaton Dam. Of these, ten are on one tributary, the Des Lacs River.

Eight of these are U.S. Fish and Wildlife Service dams and two are irrigation dams. Two dams are located on the Souris River in Canada upstream from Sherwood and six dams are located downstream from Westhope, also in Canada. Three dams are located on tributaries in Canada, upstream from Sherwood. One is located on Long Creek, one on Moose Mountain Creek, and one on Roughbark Creek. Private interests and local governmental entities have constructed a number of low-head dams on the Souris River and its tributaries in the interest of irrigation, recreation, stock watering, and domestic and industrial water supply. These reservoirs are small and are not significant factors in the flood problems of the basin. The reservoir created by Boundary Dam on Long Creek near its confluence with the Souris River in Saskatchewan impounds 48,800 acre-feet of water for thermal power production and municipal water supply for Estevan, Saskatchewan, and, since it is normally maintained as full as possible, does not provide assured flood protection.

9. During 1935 and 1936, the U.S. Fish and Wildlife Service constructed and placed in operation three migratory waterfowl refuges in the Souris River basin. One refuge is located on the Des Lacs River and two on the Souris River. The Des Lacs project consists of a series of eight dams in the vicinity of Kenmare to regulate water levels in reservoirs in the upper reach of that river. The J. Clark Salyer II project is in the river reach extending from Upham downstream to the international boundary and provides for ponding of waters, which is accomplished by a series of five low dams. The Upper Souris project, located along the Souris River northwest of Minot in Ward and Renville Counties, is a series of four dams and reservoirs, but differs from the other projects in that it includes a large storage reservoir known as Lake Darling, created by a dam located at the Ward-Renville County line (mile 429.9). The Lake Darling Dam is a compacted earth-fill structure about 30 feet in height and includes a 320-foot uncontrolled spillway section adjacent to the left abutment. The spillway has a flat crest at elevation 1598.0. A grass-lined earth emergency spillway section about 250 feet long is located in the right abutment, with crest at approximately elevation 1602. Top of dam is at elevation 1606.0, and the top width is approximately 31 feet. The reservoir is regulated through operation of two gated 10- by 12-foot concrete conduits (bottom elevation at 1577.0) which pass through the dam and discharge into a stilling basin. Lake Darling Reservoir has a capacity of about 112,000 acre-feet at spillway crest elevation and at that elevation forms a lake extending up the valley about 27 miles. The primary purpose of the reservoir is to supply water to the smaller impoundments downstream as required to maintain favorable waterfowl conditions. However, the reservoir has been operated so that at least 20,000 acre-feet of the storage capacity corresponding to a 2-foot range below the spillway crest elevation at 1598.0, has been available each spring for flood control. Depending upon predicted runoff, more flood control storage has been provided in the past. As an example, during the spring of 1949, 70,000 acre-feet of storage was made available for flood control and 60,000 acre-feet of space remained at the start of the 1969 flood. Locations of improvements by the U.S. Fish and Wildlife Service are shown on plate A-2. Two active irrigation projects are located in the basin: The Eaton Flood

Irrigation project on the Souris River near Towner and the Judge A.M. Christianson project on the Souris and Des Lacs Rivers near Burlington. The Eaton project includes a low-head dam in a reach of the river where the banks are slightly higher than the adjoining level hay lands. The Judge A.M. Christianson project includes an irrigation system consisting of two low-head dams on the Des Lacs River, one low-head dam on the Souris River and a network of irrigation ditches.

10. CLIMATOLOGY

The Souris River basin has a continental climate which is characterized by extreme variations in temperature, insufficient rainfall for high crop yields in most years, and moderate snowfall. Records of the National Weather Service for the United States portion of the basin show that temperatures have varied from a low of -54°F at Willow City, North Dakota, on 13 January 1916 to a high of 114°F at Granville, North Dakota, on 11 July 1936. Mean monthly temperatures vary from 5°F in January to 69°F in July in the United States portion and about 2°F lower in the Canadian portion. The mean annual temperature is 39°F in the United States and 37°F in Canada. Annual precipitation averages 15.5 inches over both the United States and Canadian portions of the basin. Mean precipitation is less in the western part than in the eastern part of the basin. Recorded annual precipitation indicated by stations throughout the entire basin has ranged from a minimum of 5.39 inches at Crosby, North Dakota, in 1934 to a maximum of 28.65 inches at Towner, North Dakota, in 1899. Normal monthly precipitation in the United States portion varies from a maximum of 3.48 inches in June to a minimum of 0.39 inch in February. Average annual snowfall in the United States portion is 33 inches and constitutes about 21 percent of the yearly precipitation. The Canadian portion of the basin averages 42 inches of snowfall a year, or about 27 percent of the yearly precipitation. Average annual lake evaporation is about 33 inches on the basin and is more on the western part than on the eastern part of the basin.

11. Although major storms covering large areas have occurred in the vicinity of the Souris River basin, none has centered over it during the period of record. A severe storm in the general area centered in Montana about 200 miles southwest of Minot during 17-21 June 1921. About 2.9 inches of rain fell in 6 hours and 5.3 inches in 24 hours over an area equal in size to the drainage area about Minot. At the storm center, Springbrook, Montana, 13.3 inches of rain fell within 24 hours. Another large storm occurred on 5-8 July 1928 with its center at Berthold Agency, North Dakota, about 60 miles southwest of Minot. At Berthold Agency, 6.9 inches of rain fell within 24 hours. An extremely intense rainfall on a small area occurred within the basin near Velva, North Dakota, on 10 August 1962 where a maximum depth of 10.5 inches of rainfall was reported in a period of about 4 hours. The average rainfall on the 46-square mile area of Bonnes Coulee was computed from unofficial observations as 6.2 inches. From 22-25 June 1966, an intense storm centered near Glen Ullin, North Dakota, about 100 miles southwest of Minot. At Glen Ullin, 6.24 inches of rainfall occurred within 24 hours on 24 June.

12. No regular evaporation records have been obtained in the Souris River basin. However, the average annual gross evaporation from lake areas for the entire basin is about 33 inches according to the Weather Bureau Technical Paper No. 37: "Evaporation Maps for the United States." Net evaporation (gross evaporation less precipitation) averages about 17.5 inches per year.

13. DRAINAGE AREAS

Large portions of the Souris River basin consist of relatively flat land, with no defined drainage courses, containing numerous potholes, small lakes and intermittent lakes. These areas are considered as non-contributing drainage areas as they seldom, if ever, contribute runoff to the Souris River. Primary contributing and total drainage areas at pertinent locations in the United States are given in table A-1.

Table A-1 - Drainage Areas at Pertinent Locations on the Souris River and Tributaries in the United States

Location	Drainage Area in Sq. Mi. Primary Contributing	Total(1)
Souris River near Sherwood, ND	3,173	8,633
Souris River at Lake Darling Dam	3,400	9,160
Souris River near Foxholm, ND	3,270	9,470
Souris River at Burlington Damsite	3,290	9,490
Des Lacs River at Middle Des Lacs Dam (Dike No. 4) near Kenmore, ND	274	615
Des Lacs River at Foxholm, ND	539	939
Souris River above Minot, ND, USGS Gage	3,900	10,600
Gassman Coulee at Highways 2 and 52	35	61
Souris River at Minot, ND (Main St.)	3,960	
Souris River at Sawyer, ND	4,230	
Souris River at Velva, ND	4,330	
Souris River near Verendrye, ND	4,400	11,300
Wintering River near Karlsruhe, ND	285	705
Souris River near Towner, ND	4,600	12,100
Souris River near Bantry, ND	4,700	12,300
Willow Creek near Willow City, ND	730	1,160
Deep River near Upham, ND	370	975
Cutbank Creek near Granville, ND	244	534
Boundary Creek near Landa, ND	170	230
Souris River near Westhope, ND	6,600	16,900

(1) Total areas for locations listed on the Souris River include about 1,120 square miles which are considered to never contribute to the Souris River. The noncontributing areas are interior areas located above the Sherwood gaging station. The drainage areas listed for Souris River near Sherwood and at Lake Darling Dam have been adjusted for this study. The remaining areas are as per the USGS Water Supply papers.

14. Drainage areas for the gaging station on the Souris River near Sherwood, North Dakota, and for upstream locations on the Souris River and its tributaries have been furnished by the Province of Saskatchewan, Department of the Environment, Hydrology Branch, at Regina, Saskatchewan. Included are effective drainage areas (assumed contributing to floods of 50 percent exceedence frequency) and gross drainage areas (contributing to floods of about the probable maximum flood magnitude). The drainage area boundaries for these categories were furnished by the Canadian engineers. These drainage boundaries were examined by the St. Paul District on detailed topographic maps covering the basin and appear to be reasonable and were accepted for the hydrology studies above Sherwood. The drainage areas were redefined in terms of primary, secondary, and non-contributing drainage areas. Plate A-3 shows the drainage are delineation above Lake Darling. Drainage areas at pertinent locations at and above Sherwood are given in table A-2. Total drainage areas (including additional non-contributing drainage areas) are published in annual reports of "Surface Water Data - Saskatchewan," by the Water Survey of Canada.

Table A-2 - Drainage Areas at Pertinent Locations in Souris River Basin above Sherwood, North Dakota

Gaging Station	Drainage Areas in Square Miles Primary	Secondary	Non-Cont.	Gross
Souris River near Estevan, Sask.	1,612	2,397	349	4,358
Moose Mountain Creek near Oxbow, Sask.	1,064	1,277	0	2,341
Souris River at Oxbow, Sask.	3,068	4,289	1,129	8,486
Souris River near Sherwood, ND	3,173	4,331	1,129	8,633

Notes: Primary area contributes to all floods.
Secondary area contributes for floods from about 50-year to the probable maximum flood magnitude.
Gross area contributes for floods of about the probable maximum flood magnitude.
These areas were used for unit hydrograph and flood studies at and above Sherwood.

15. RUNOFF AND STREAMFLOW DATA

Records of river stage and streamflow on the Souris River within the United States, as obtained by the Geological Survey, are fairly complete. At present, six gaging stations are in operation on the Souris River, including one near each of the two crossings of the international boundary. These stations are located near Sherwood, near Foxholm, above Minot, near Verendrye, near Bantry, and near Westhope. At each of these stations, through 1981, 44 years or more of records are available. The longest combined record is at the Minot gage where streamflow data have been obtained since May 1903. Another gaging station was operated on the Souris River near Towner from 1933 to 1941. However, records for this station are incomplete. Seven gaging stations are being operated on the Souris River in Canada by the Water Survey of Canada. Five stations between the source and Sherwood are located near Halbrite, near Estevan, at Roche Percee, near Oxbow, and near Glen Ewen, all in Saskatchewan. Two

stations, downstream from Westhope, are located near Melita and at Wawanesa, Manitoba. Tributaries with more than 22 years of streamflow records are Long Creek, Des Lacs River, and Wintering River in the United States and Long Creek and Moose Mountain Creek in the Upper Souris basin in Canada. Several additional tributary stations, which were established in recent years, have less than 15 years of records. Monthly stage records are available for Lake Darling since 1936. The maximum streamflow of the year in the vicinity of Minot usually occurs in April or May, following the spring snowmelt. Occasionally these high flows are augmented by accompanying rains. Runoff in the basin decreases during the summer months. Flow during the fall and winter months is very low and no flow has occurred in many months. Tables A-3 and A-4 contain pertinent data for all streamflow stations, including periods of record, total drainage areas, gage zeros, and maximum and minimum discharges. Data on streamflow at locations in the Canadian portion of the basin through 1964 are given in "Surface Water Supply of Canada, Arctic and Western Hudson Bay Drainage." Beginning with 1965 data, the Canadian records have been published in reports entitled "Surface Water Data, Saskatchewan (or Manitoba), (year), Water Survey of Canada." Drainage areas for all Souris River gaging stations in the United States were recently revised by the Geological Survey because of a reduction in the drainage area of Long Creek.

16. The extreme variations in the annual runoff near Sherwood, since April 1930, are from a minimum of 1,130 acre-feet in the water year 1937 to a maximum of about 637,000 acre-feet in the water year 1976. Monthly runoff has varied from zero for various summer, fall, and winter months to a maximum of 401,000 acre-feet in April 1976. The flow at the international boundary crossing near Sherwood is partially regulated by Boundary Dam on Long Creek and several smaller impoundments, all within the Canadian portion of the Upper Souris River basin. The average annual runoff near Sherwood for the 50-year period, 1931-1980, was 102,900 acre-feet which is equivalent to a depth of about 0.63 inch on the primary contributing drainage area of 3,173 square miles. The average annual runoff of the Souris River above Minot for the 77-year period, 1904-1980, amounts to 123,900 acre-feet.

17. However, the flow in the vicinity of Minot has been regulated by Lake Darling Reservoir since its construction in 1936. The average annual runoff at Minot is equivalent to a depth of about 0.59 inch on the primary contributing drainage area of 3,900 square miles. Usually about 62 percent of this runoff occurs in the months of April, May and June under existing conditions with Lake Darling in operation. The maximum recorded annual runoff during the 77-year period occurred in 1976 and amounted to 801,900 acre-feet, of which about 620,000 acre-feet were attributable to the spring flood. The lowest recorded annual runoff during this same period amounted to 939 acre-feet in 1937.

18. Flood volumes of seven major floods at the Lake Darling damsite are given in table A-5. Included are volumes in acre-feet, duration in days, and inches of runoff depth above approximate channel capacity of 2,000 cfs and also above channel design capacity of 5,000 cfs at Minot. The runoff

Table A-3 - Streamflow Records and Characteristics - Canadian Gaging Stations - Souris River Basin(1)

Station	River miles above mouth(7)	Total drainage area(2) sq. mi.	Gage zero elevation above msl	Period of Record From	Period of Record To	Maximum Flow Data: Date of maximum discharge	Maximum Flow Data: Discharge cfs	Maximum Flow Data: Gage height ft.	Minimum Flow Data: Date of minimum discharge	Minimum Flow Data: Discharge cfs	Average discharge cfs
Yellow Grass Ditch near Yellow Grass, Sask.	729	896		Mar 57	Date	16 Apr 69	753(4)		Each year	0.0	11.7(3)
Souris River near Halbrite, Sask.	688	1,370		Mar 59	Date	12 Apr 69	2,280		Each year	0.0	30.3(3)
Roughbark Creek above Roughbark Res., Sask.		69.6		Mar 59	Date	11 Apr 69	850(4)		Each year	0.0	4.8(3)
Roughbark Creek below Roughbark Res., Sask.		112		Mar 60	Date	11 Apr 69	959		Each year	0.0	5.8(3)
Gibson Creek near Radville, Sask.		271		Mar 59	Date	6 Apr 69	943(4)		Each year	0.0	5.9(3)
Long Creek near Maxim, Sask.		609		Mar 59	Date	8 Apr 69	2,910		Each year	0.0	24.1(3)
Long Creek at western crossing of International Boundary		1,320(5)	1894.00	Mar 59	Date	10 Apr 69	3,970	12.17	Each year	0.0	28.9
Long Creek near Crosby, N. D.		1,370(6)	1870(8)	Apr 44	Sep 65	23 Apr 48	6,240	16.10	Each year	0.0	25.8
Long Creek near Noonan, N. D.		1,790(5)	1840(8)	Oct 59	Date	10 Apr 69	4,980	16.23	Each year	0.0	36.1
Long Creek near Estevan, Sask.				Jul 11	May 23						
		1,970(6)		Mar 59	Date	11 Apr 69	3,990(4)		Many years	0.0	26.7
Long Creek near Estevan, Sask.				Apr 35	Oct 57	19 Apr 51	1,330(4)		Many years	0.0	40.1(3)
Coulee, West of Boundary Res. near Estevan, Sask.		104		Mar 60	Oct 69	3 Apr 60	22.8		Each year	0.0	0.16(3)
Souris River near Estevan,	624			Jul 11	May 23						
Sask.		4,500(6)		Apr 33	Date	24 Apr 48	7,580(4)		Many years	0.0	54.5
Short Creek near Roche Percee, Sask.		480		Mar 60	Date	7 Apr 69	1,760	14.33	Each year	0.0	7.0
Souris River at Roche Percee, Sask.	611	5,060(6)		Mar 56	Date	15 Apr 69	7,190(4)		Many years	0.0	100(3)
Moose Mountain Creek below Moose Mountain Lake	107	865		Mar 59	Date	11 Apr 69	503(4)		Each year	0.0	7.0(3)
Moose Mountain Creek above Kisbey Irrigation Project	70	1,190		Mar 60	Date	11 Apr 69	1,050		Each year	0.0	14.0(3)
Moose Mountain Creek below Kisbey Irrigation Project	50	1,390		Mar 60	Date	15 Apr 69	741		Each year	0.0	11.7(3)
Moose Mountain Creek near Oxbow, Sask.	3	2,310		Mar 56	Date	10 Apr 69	3,980(4)		Each year	0.0	41.7(3)
Moose Mountain Creek near	1			Sep 13	Oct 17						
Oxbow, Sask.				Apr 33	Oct 55	3 Apr 55	1,650(4)		Most years	0.0	68.7(3)
Souris River near Oxbow, Sask.	552	8,770(6)		Apr 43	Date	11 Apr 69	3,450(4)		Many years	0.0	97.9
Souris River near Glen Ewen,	533			Jul 11	Oct 17						
Sask.	533	8,810(6)		Mar 70	Date	16 May 70	2,900(4)		Mar 15	0.0	

(1) Data as of 31 December 1970. Included are stations upstream from international boundary near Sherwood only.
(2) Drainage areas listed are total drainage areas. A large portion of many of the drainage areas given is normally noncontributing.
(3) Average discharge is for the months of March through October only.
(4) Maximum daily discharge.
(5) Revised USGS drainage area which is about 710 sq. mi. less than latest published (unrevised) area by Water Survey of Canada.
(6) Drainage area in Canadian publications reduced by 710 sq. mi., the same difference from USGS revised areas at Noonan and Sherwood Stations.
(7) Approximate mileage as determined in this office from Canadian quadrangle maps.
(8) Approximate from topographic map.

Table A-4 - STREAMFLOW RECORDS AND CHARACTERISTICS (USGS GAGING STATIONS) - SOURIS RIVER BASIN IN THE UNITED STATES (1)

Station	River Miles Above Mouth	Total Drainage Area (sq mi)	Gage Zero Elevation Above MSL (1929 adj)	Period of Record From	Period of Record To	Maximum Flow Data: Date of Maximum Discharge	Maximum Flow Data: Discharge (cfs)	Maximum Flow Data: Gage Height (ft)	Minimum Flow Data: Date of Minimum discharge	Minimum Flow Data: Discharge (cfs)	Average Discharge (cfs)
Long Creek at western crossing of international boundary		1,320	1894.00(2)	1 Mar 59	Date	1 Apr 76	4,690	12.05	Each year	0.0	43.2
Long Creek near Crosby		1,370	1870 (3)	1 Apr 44	30 Sep 65	23 Apr 48	6,240	16.10	Each year	0.0	25.8
Long Creek near Noonan		1,790	1840 (3)	1 Oct 59	Date	31 Mar 76	6,310	17.61	Each year	0.0	55.6
Short Creek below international boundary near Roche Percee, Sask.		480		1 Mar 60	Date	7 Apr 69	1,700	14.33	Each year	0.0	14.1
Souris River near Sherwood	511.4	8,633	1603.73	1 Mar 30	Date	10 Apr 76	14,800	25.15	In several years	0.0	142
Souris River near Foxholm	417.7	9,470	1572.00	22 Jun 04	28 Nov 05						
	414.4	9,470	1561.20	1 Apr 37	25 Mar 38						
	414.5	9,470	1560.73	25 Mar 38	Date	16 Apr 76	8,600	17.17	In several years	0.0	150
Des Lacs River at Foxholm		939	1632.98	23 Jun 04	31 Jul 06						
	23.0	939	1632.98	1 Oct 45	Date	19 Apr 79	4,260	21.23	In several years	0.0	32.1
Souris River at Minot	377.6	10,600	1533.25	5 May 03	30 Sep 28						
	377.6	10,600	1533.25	1 Oct 29	30 Sep 34						
Souris River near Minot	366.8	10,600	1526.55	1 Oct 28	30 Sep 29						
Souris River above Minot	388.5	10,600	1545.75	1 Oct 34	Date	20 Apr 04	12,000	21.90	In several years	0.0	171
Souris River near Verendrye	302.0	11,300	1466.84	1 Apr 37	3 Mar 38						
	302.0	11,300	1464.87	4 Mar 38	Date	19 Apr 76	9,900	17.84	11 Aug 37 (4)	0.3	220
Wintering River near Bergen		176	1587.91	1 Oct 56	Date	10 Apr 69	900	5.90	Each year	0.0	6.31
Wintering River near Karlsruhe		705	1480 (3)	1 Mar 37	Date	7 Apr 49	3,000	12.00	Many years	0.0	12.8
Souris River at Towner	254.7	12,100	1444.18	1 Mar 33	28 Oct 34						
Souris River near Towner	264.7	12,100	1443.50	23 Mar 35	31 Jul 41	1 Apr 39	1,150	12.53	In several years	0.0	
Souris River near Bantry	228.0	12,300	1427.56	1 Mar 37	Date	23 Apr 76	9,330	14.59	In several years	0.0	238
Willow Creek at Dunseith		142	1700.00	1 Sep 53	30 Sep 70	19 Apr 69	476	14.60	Many years	0.0	15.5
Oak Creek near Bottineau		59	2130.00	1 Oct 53	Date	3 May 75	148	9.70	Each year	0.0	4.28
Willow Creek near Willow City		1,160	1430 (3)	1 Aug 56	Date	12 Apr 69	5,900	16.76	Each year	0.0	46.9
Deep River near Upham		975	1430 (3)	1 Sep 57	Date	12 Apr 69	6,760	18.18	Each year	0.0	20.4
Egg Creek near Granville		289	1478.14	1 Oct 56	Date	10 Apr 69	1,710	7.28	Each year	0.0	6.55
Cutback Creek near Granville		534	1477.25	1 Oct 56	30 Sep 80	29 Mar 76	780	4.60	Each year (5)	0.0	6.05
Boundary Creek near Landa		230	1420.03	1 Sep 57	Date	9 Apr 69	3,580	12.70	Each year	0.0	12.6
Souris River near Westhope	160.8	16,900	1405.04	26 Jul 29	28 Mar 38						
	154.5	16,900	1402.45	28 Mar 38	Date	26 Apr 76	12,600	19.16	In several years	0.0	264

(1) Data as of 30 September 1980.
(2) International boundary survey, feet above msl, 1929 adjustment.
(3) Gage zero elevation from topographic map.
(4) Minimum recorded, 0.3 cfs 11-19 August 1937, 10-21 October 1939.
(5) No flow after 23 April 1960 until 11 April 1969.
NOTE: Drainage areas listed are total drainage areas. A large portion of many of the areas given is probably noncontributing.

Table A-5- Flood Volumes, Durations, and Depths of Runoff for Major Floods at Lake Darling Damsite

Year	Volume above ave. channel capacity of 2,000 cfs (ac-ft)	Duration in days above ave. channel capacity	Inches of Runoff from Primary Drainage Area	Inches of Runoff from Total Drainage Area	Volume above Design Disch. of 5,000 cfs (ac-ft)	Duration in Days Above Design Disch.	Inches of Runoff from Primary Drainage Area	Inches of Runoff from Total Drainage Area
1882	392,000	47	2.23	0.77	176,000	28	1.00	0.35
1904	315,700	44	1.80	0.62	117,200	26	0.67	0.23
1948	122,440	23	0.70	0.24	32,800	9	0.19	0.06
1969	156,340	22	0.89	0.31	51,500	14	0.29	0.10
1974	111,830	25	0.64	0.22	6,520	4	0.04	0.01
1975	162,650	34	0.93	0.32	23,580	12	0.14	0.05
1976	329,800	42	1.89	0.66	120,670	20	0.69	0.24
1979	195,840	34	1.12	0.39	48,460	12	0.28	0.10

depths in inches are based on the primary drainage area of 3,400 square miles and total drainage area of 9,160 square miles above the Lake Darling damsite. The 1904 flood hydrograph at the damsite is estimated as 9 percent less than the observed discharge at Minot and the 1882 flood hydrograph is esimtated as 15 percent greater than the 1904 flood. The 1948, 1969, 1974, 1975, 1976 and 1979 floods at the damsite are estimated as 7.6 percent more than the observed flows at the Sherwood gaging station.

19. FLOOD FREQUENCY CURVES

20. General

Discharge-frequency curves have been derived for the Souris River near Sherwood, Minot, Sawyer, Velva, Verendrye, Bantry, and Westhope. Conditions prior to the construction of Lake Darling Dam in 1936 are referred to in this report as natural conditions. Conditions from 1936 to the present are called existing conditions. Conditions, as they would be after the proposed project is in place, are called "modified," "proposed" or "with-project" conditions.

21. Minot, the principal damage center, is located on the Souris River about 136 river miles downstream from the Canadian border. Sawyer, Velva, and Verendrye are about 32, 46 and 67 river miles downstream from Minot, respectively. Bantry and Westhope are about 149 and 222 river miles downstream from Minot, respectively. The river passes through Lake Darling Reservoir, 53 river miles above Minot. This reservoir, placed in operation in 1936 by the U.S. Fish and Wildlife Service, has a useable capacity of 118,500 acre-feet and a total capacity of 122,000 acre-feet at the crest of spillway. The Des Lacs River, a tributary, joins the Souris River 19 miles upstream from Minot. Eight wild fowl refuge ponds near Kenmare with a combined capacity of about 49,000 acre-feet, provide some regulation of the Des Lacs River.

22. Streamflow records are available at U.S. Geological Survey gaging stations on the Souris River near Sherwood (at the upper crossing of the international boundary) since March 1930; near Foxholm (below Lake Darling and above the mouth of the Des Lacs River) since October 1936; above Minot (3 1/2 miles west of Minot or 12 river miles above the center of Minot) and other nearby locations since May 1903; near Verendrye since April 1937; near Bantry since March 1937; and near Westhope since April 1930. Discharge records are available on the Des Lacs River at Foxholm (below the Des Lacs National Wildlife Refuge) for June 1904 through July 1906 and from October 1945 to date. Discharge records are available on the Wintering River near Karlsruhe (4 miles upstream from the Souris River) since March 1937. Pertinent data on these and other Geological Survey gaging stations which were not used in frequency studies are given in table A-4. Discharge frequency computations and curves include records through the 1981 water year.

23. Large areas in the basin do not normally contribute direct surface runoff because potholes, swamps and other depressed areas lack drainage outlets. The primary contributing drainage areas are used in the frequency analysis. Drainage areas used in the flood frequency investigations are given in table A-1.

24. Sherwood

An annual instantaneous discharge frequency curve for the Souris River near Sherwood was computed according to the guidelines set forth in the Water Resources Council's Bulletin No. 17B and HEC computer program 723-X6-L7550, "Flood Flow Frequency Analysis." This curve is based on 52 years of record (1930-1981) plus estimated peaks for the two historical floods, 1904 and 1882, which were estimated from the Minot peaks. This curve is based on "expected probability" "P_n" and has a mean logarithm of 3.0719, standard deviation of .5870, adopted skew of -.2487 and an adjusted period of record of 100 years. The frequency curve and .05 and .95 confidence limit curves are shown on plate A-4. The summary of these peak discharges and the Weibull plotting positions are shown on table A-6.

25. Souris River near Foxholm

The partial duration instantaneous peak discharge frequency curve for the Souris River near Foxholm is based on 45 years of record (1937-1981), plus the estimated peak for 1936 based on records at Minot, for a total of 46 years. The records since 1936 are all for existing conditions with Lake Darling Dam. From a study of observed flows for the Souris River near Foxholm and Minot, the observed peaks at Foxholm are 86 percent of the Minot peaks and this percentage was used to get estimated peak flows for the 1904 and 1882 floods at Foxholm. Weibull plotting positions for the existing discharge-frequency curves are shown on table A- 7 and are the same as for Minot existing conditions curve adjusted to the 100-year period (1882-1981). The method of computing plotting positions for 100 years is the same as used for Minot. The Souris River near Foxholm frequency curve for existing conditions is shown on plate A-4.

26. Des Lacs River at Foxholm

In order to supplement the 36 years of streamflow records, 1946 through 1981, peak flows were estimated from other stations for the years 1937 through 1945. Studies of available records indicated that, of the peak flows at Minot which originated below Lake Darling, about 85 percent of the peak flow was observed on the Des Lacs River at Foxholm. Consequently, for the years 1937 through 1945, the outflows from Lake Darling were subtracted from the observed flows at Minot to obtain the peak flows originating below Lake Darling. Then 85 percent of these peak values were used as the peak flows on the Des Lacs River at Foxholm. The incomplete records of July 1904 through September 1906 were not used, since the peak flow data were not reliable and flow conditions were different without the wildlife pools. Flood peaks for 1882 and 1904 were estimated as 14 percent of the Minot peak flows. Since 14 percent of the

Table A-6 - Plotting Points for Discharge-Frequency, Floods of Record
Souris River near Sherwood, ND (Annual Instantaneous Peaks)

Date	Water Year	Peak Discharge (cfs)	Weibull Plotting Position (Percent)
	1882	21,800(1)	0.99
Apr	1904	15,000(2)	1.98
10 Apr	1976	14,800	3.41
11 Apr	1969	12,400	5.27
30 Apr	1979	8,550	7.14
28 Apr	1948	7,400	9.01
5 May	1975	6,810	10.87
19 Apr	1974	6,400	12.74
12 Apr	1943	5,320	14.60
5 Apr	1955	5,210	16.47
16 Apr	1956	3,560	18.34
27 Mar	1972	3,310	20.20
17 May	1970	2,750	22.07
11 Apr	1949	2,720	23.93
10 May	1951	2,680	25.80
8 Apr	1960	2,670	27.67
28 Mar	1939	2,480	29.53
18,19 Apr	1947	2,250	31.40
30 Mar	1946	2,010	33.26
9 Jul	1953	1,780	35.13
5 Apr	1942	1,700	37.00
18 Apr	1950	1,610	38.86
5 Apr	1978	1,570	40.73
18 Apr	1971	1,480	42.59
2 Apr	1966	1,410	44.46
2 Apr	1958	1,380	46.33
31 Mar	1933	1,370	48.19
25 Apr	1936	1,270	50.06
5 Jul	1944	1,240	51.92
3 Apr	1952	1,200	53.79
20,27 Apr	1938	1,040	55.65
9 Jun	1965	1,030	57.52
14 Apr	1941	1,030	59.39
11 Apr	1930	956	61.25
15 Jun	1962	891	63.12
5 Apr	1964	880	64.98
18 Jun	1954	811	66.85
25 Mar	1957	750	68.72
23 Mar	1959	740	70.58
21 Feb	1981	660	72.45
4 Apr	1980	630	74.31
15 May	1967	613	76.18
25 Mar	1963	470	78.05
9 Mar	1968	400	79.91
16 Mar	1934	344	81.78
5 Jul	1935	200	83.64
20 Mar	1961	160	85.51
16 Mar	1973	150	87.38
14 Apr	1937	125	89.24
15 Apr	1940	120	91.11
6 Apr	1932	90	92.97
17 Apr	1977	76	94.84
28 Mar	1945	60	96.71
14 Apr	1931	19	98.57

(1) Estimated by Corps of Engineers from Minot peaks.
(2) Estimated by Corps of Engineers and USGS, based on 1976 peak and observer's report that 1904 peak stage was higher than 1976.

Table A-7
Plotting Points for Discharge-Frequency Floods of Record, Souris River near Foxholm, North Dakota (Partial-Duration Series)

Date	Year	Peak Discharge cfs	Weibull Plotting Position (percent)
	1882	13,600(1)	1.00
17 Apr	1976	8,600	2.00
Apr	1904	7,920(1)	3.00
17,18 Apr	1969	5,380	4.00
9 May	1979	5,330	5.00
23 May	1975	5,260	5.90
23 Apr	1974	3,400	8.12
16 May	1948	3,040	10.33
25 Apr	1943	2,990	12.55
19,24 May	1970	2,810	14.77
21 Apr	1955	2,330	16.98
14 May	1951	2,120	19.20
22 Apr	1956	1,890	21.42
4 Apr	1972	1,800	23.63
13,14 Jul	1953	1,480	25.85
28 Apr	1947	1,350	28.07
26 Apr	1950	1,290	30.28
20 Jun	1975	1,210	32.50
1-5 Jul	1976	1,130	34.72
22 Apr	1971	1,070	36.93
14 Apr	1951	1,050(2)	39.15
1 Apr	1947	1,020(2)	41.37
14 Apr	1960	926	43.58
18 Jun	1970	920	45.80
15 Jun	1965	917	48.02
30 Apr	1980	884	50.23
18 Apr	1948	869(2)	52.45
15 Apr	1949	690	54.67
17 Apr	1939	663	56.88
15-23 Mar	1949	612(2)	59.10
6 Jun	1956	600	61.32
7 Apr	1966	576	63.53
19 Jun	1972	560	65.75
20,21 Jul	1971	530	67.97
20 Oct	1939	504	70.18
4 Jul	1947	493(2)	72.40
19 Apr	1941	486	74.62
17 Jul	1969	468	76.83
5 Apr	1938	464	79.05
24 Jun	1954	444	81.27
14 May	1960	435	83.48
6 Apr	1973	424	85.70
28,29 Aug	1967	399	87.92
30 Apr	1958	368	90.13
14 Apr	1953	360	92.35
29 Apr	1977	336	94.57
15 Aug	1978	335	96.78
22 Apr	1959	329	99.00

(1) Estimated by Corps of Engineers for existing conditions with Lake Darling in operation.
(2) Instantaneous peak estimated from mean daily peak.

1904 peak is only about 1,700 cfs, this flow was not included with the partial-duration plotting points. The frequency curve was computed by the same method used for the curve at Minot, assuming that all flood peaks above 2,500 cfs are known for 100 years, and complete records or estimates of peak flows are available for 45 years (1937-1981). The frequency, which is for partial duration series, instantaneous discharges, is shown on plate A-4. Weibull plotting positions for the historic adjusted frequency curve are listed on table A-8.

27. Minot

Streamflow at Minot has been regulated by Lake Darling Dam since April 1936. For this report, existing conditions are conditions with Lake Darling Dam in operation. Natural conditions are conditions prior to the construction of Lake Darling Dam. Since Lake Darling Dam has been in operation, major flood events have occurred at Minot in six different years, 1969, 1970, 1974, 1975, 1976 and 1979. Two large earlier floods are known to have occurred in 1904 and 1882. The 1904 flood had a peak flow of 12,000 cfs (cubic feet per second) on 20 April, according to the U.S. Geological Survey, and is the largest flood during its period of record. The 1882 flood has been reported as at least 3 feet higher than the 1904 flood, and its peak has been estimated by the Corps of Engineers as 22,800 cfs. In order to obtain the peak flows at Minot under existing conditions, the 1904 and 1882 flood inflows into Lake Darling were estimated from the observed 1904 and the estimated 1882 natural floods at Minot. The floods were routed through Lake Darling and downstream to Minot, resulting in regulated peak flows of 9,500 cfs for the 1904 flood and 15,800 cfs for the 1882 flood at Minot.

28. The frequency curve for existing conditions at Minot was computed graphically, using the regulated peaks for 1882, 1976, 1969, 1904, 1979 and 1975 as the six largest peaks in 100 years (1882-1981. The remaining observed regulated peaks, for 46 years, were distributed within the 100-year period using a method of M.A. Benson published in "Transactions, American Geophysical Union," June 1950. The graphical method was used because of the Lake Darling effect on all peak flows downstream of Lake Darling. Analytical computations were used as a guide to determine the upper end of the natural condition frequency curve which in turn was used as a guide for the upper end of the existing condition frequency curve. The Weibull plotting positions are used and, therefore, the frequency curve results are based on "expected probability," "P_n." The peak discharges and plotting positions are shown in table A-9. This frequency curve, which reflects the beneficial effect of the Lake Darling Reservoir on smaller floods, is shown on plate A-4.

29. The discharge-frequency curves for natural conditions, without Lake Darling, for Minot was computed by statistical methods for the annual natural peaks and graphically for the partial duration series. All peak discharges since 1936 were regulated by Lake Darling and, therefore, were adjusted to natural conditions by using flow records at Sherwood, Foxholm and at Minot.

Table A-8
Plotting Points for Discharge-Frequency, Observed or Estimated Discharge Peaks, Des Lacs River at Foxholm, North Dakota (Partial-duration series)

Date	Year	Peak Discharge cfs	Weibull Plotting Position (percent)
19 Apr	1979	4,260	1.00
30 Apr	1970	3,660	2.00
	1882	3,190	3.00
29 Apr	1975	2,670	4.00
10 Apr	1969	2,460	6.26
4 Apr	1949	2,000	8.52
6 Apr	1951	1,800	10.79
25 Mar	1976	1,550	13.05
25 Mar	1939	1,220	15.31
27 Jun	1944	1,210	17.57
9 Apr	1976	1,070	19.83
16 Mar	1972	1,030	22.10
27 Mar	1960	1,020	24.36
16 Apr	1950	1,010	26.62
23 May	1972	990	28.88
31 Mar	1943	980	31.14
9 Jun	1963	934	33.40
31 Mar	1955	900	35.67
1 Apr	1952	850	37.93
2 Jul	1953	775	40.19
27 Mar	1978	700	42.45
12 Apr	1956	696	44.71
14 Mar	1974	650	46.98
24 Mar	1947	640	49.24
9 May	1979	630	51.50
7 Apr	1974	620	53.76
10 Apr	1972	615	56.02
19 Feb	1981	580	58.29
21 Jun	1975	580	60.55
22 May	1974	560	62.81
13 May	1950	540	65.07
25 Mar	1967	530	67.33
20 Jun	1973	529	69.60
5 Apr	1942	511	71.86
19 Apr	1948	505	74.12
23 Aug	1972	450	76.38
29 Mar	1958	430	78.64
15 Apr	1965	406	80.90
29 Apr	1951	402	83.17
14 Mar	1945	378	85.43
3 Apr	1964	355	87.69
11 Apr	1947	352	89.95
25 Jun	1947	316	92.21
16 Jun	1965	302	94.48
27 Jul	1963	280	96.74
13 Mar	1966	250	99.00

NOTES: 1882 peak discharge was estimated as 14 percent of Minot peak flow.
1937-45 peak flows were estimated as 85 percent of the difference of flows of Souris River above Minot and Souris River near Foxholm.
1946-81 peak discharges are observed flows.

Table A-9
Plotting Points for Discharge Frequency, Floods of Record, Souris River at Minot, North Dakota (partial-duration series)

Date	Year	Peak Discharge cfs	Weibull Plotting Position (Percent)
		Existing Conditions	
	1882	15,800(1)	1.0
20 Apr	1904	9,500(1)	2.0
17 Apr	1976	9,350	3.0
19 Apr	1969	6,020	4.0
9 May	1979	5,960	5.0
13 May	1975	5,700	5.9
25 Apr	1974	3,530	8.07
12 May	1970	3,320	10.23
17 May	1948	2,700	12.40
26 Apr	1943	2,480	14.56
11 Apr	1972	2,380	16.73
2 July	1953	2,320	18.89
16 May	1951	2,280	21.06
6 Apr	1949	2,250	23.22
22 Apr	1955	2,220	25.39
8 Apr	1951	2,190	27.55
23 Apr	1956	1,930	29.72
26 Mar	1939	1,480	31.88
28 June	1944	1,400	34.05
3 Apr	1947	1,360	36.21
28 Apr	1950	1,340	38.38
29 Apr	1947	1,295	40.54
2 Apr	1955	1,270	42.71
16 June	1965	1,220	44.87
19 Apr	1948	1,205	47.04
18 June	1970	1,200	49.20
7 July	1971	1,180	51.37
1 July	1976	1,120	53.53
28 Mar	1978	1,100	55.70
14 June	1972	1,100	57.86
23 Apr	1971	1,090	60.03
1 Apr	1952	1,080	62.19
29 Mar	1960	1,000	64.36
15 Mar	1974	990	66.52
15 Apr	1960	975	68.69
24 May	1972	940	70.85
9 June	1963	834	73.02
21 June	1973	721	75.18
4 June	1943	698	77.35
18 Apr	1939	680	79.51
7 June	1956	670	81.68
11 May	1949	660	83.84
5 June	1953	633	86.01
19 Feb	1981	630	88.17
30 Mar	1958	625	90.34
5 Apr	1942	620	92.50
30 Mar	1971	600	94.67
8 July	1969	600	96.83
2 July	1979	580	99.00

(1) Estimated by Corps of Engineers for existing conditions with Lake Darling Dam in operation.

The annual instantaneous discharge-frequency curve for the Souris River near Minot was computed according to the guidelines set forth in the Water Resources Council's Bulletin No. 17B and HEC computer program 723-X6-L7550, "Flood Flow Frequency Analysis." The curve is based on 77 years of record (1904, 1905-1981) plus estimated peak for the historical flood of 1882. This natural condition frequency curve computed using the probability "P_n" and has a mean logarithm of 3.1452, standard deviation of 0.4679 adopted skew of 0.10 and an adjusted period of record of 100 years. The partial duration series natural frequency curve for Minot was derived for the same period of records as the annual peaks curve. The partial duration curve above 35% is the same as the annual series curve. The Bulletin 17B and graphical frequency curves discussed above are shown on plate A-4 along with the .05 and .95 confidence limit curves. The summary of the peak discharges and the Weibull plotting positions are shown on table A-10 for the annual series and on table A-11 for the partial duration series.

30. Verendrye

All of the streamflow records for the station at Verendrye, which started in April 1937, are for existing conditions with Lake Darling in operation. Discharge frequency curves were derived graphically using Weibull's plotting positions from 46 years of record (1937-1981), including the estimated peak for 1936 based on records at Minot. This curve is based on partial duration series and instantaneous peak discharges and is shown on plate A-4. The peak discharge data and the plotting positions for the Verendrye 46-year curve are shown on table A-12. This curve clearly shows the effect of Lake Darling regulation on larger floods. No data are availablve at Verendrye on the extremely large floods of 1904 and 1882. The frequency curves for Verendrye from 46 years of record were adjusted by means of Minot frequency curves to be consistent with the period used at Minot, including the very large floods. The method of adjustment is illustrated on plate A-4, which shows the frequency curves for partial duration series instantaneous discharges. A frequency curve was derived for Minot from the same 46-year period as that used for Verendrye. The Minot and Verendrye 46-year frequency curves were both plotted on a logarithmic probability grid, and the Minot 100-year curve was then added. The vertical distances between the Minot 46-year and 100-year curves at selected probabilities were applied to the Verendrye 46-year frequency curve to obtain the adjusted 100-year Verendrye frequency curve representing a 100-year period.

31. Frequency curves for natural conditions at Verendrye were obtained by multiplying the Minot discharge frequency curve for natural conditions by 1.08. This factor was obtained by comparing the respective frequency curves for existing conditions, flood peaks of record, and the primary contributing drainage areas at the two locations. The upper end of the Verendrye existing curve, above about 1%, was adjusted slightly downward to be consistent with the natural frequency curve. The natural frequency curve at Verendrye, which is based on Minot 100-year adjusted period (1882-1981), was used as a guide to determine the limiting slope of the upper end

Table A-10 -Plotting Points for Discharge Frequency, Floods of Record, Souris River at Minot, North Dakota (Annual Series)

Natural Conditions (1)

Date	Year	Peak Discharge (cfs)	Weibull Plotting Position (percent)	Date	Year	Peak Discharge (cfs)	Weibull Plotting Position (percent)
	1882	22,800 (2)	0.99	20 Apr	1912	1,200	50.50
20 Apr	1904	12,000	2.12	31 Mar	1938	1,100	51.77
Apr	1976	11,800	3.39	13 Apr	1909	1,090	53.04
19 Apr	1969	10,000	4.67	10 Apr	1906	1,090	54.31
3 May	1979	9,250	5.94	4 Apr	1913	1,080	55.59
9 May	1975	8,100	7.21	20 Apr	1914	1,080	56.86
17 May	1948	7,900	8.49	17 Apr	1941	1,080	58.13
25 Apr	1974	6,000	9.76	11 Jun	1965	1,050	59.41
13 Apr	1943	5,700	11.03	6 Apr	1933	1,040	60.68
22 Apr	1955	5,400	12.31	9 Jun	1963	1,020	61.95
6 May	1916	4,260	13.58	8 Apr	1964	940	63.22
30 Apr	1927	3,900	14.85	14 Apr	1930	920	64.50
18 Apr	1956	3,700	16.12	20 Jun	1954	850	65.77
1 May	1970	3,560	17.40	10 Jul	1921	790	67.04
30 Apr	1923	3,460	18.67	30 Mar	1918	790	68.32
18 Apr	1925	3,450	19.94	25 Mar	1959	780	69.59
14 Apr	1949	3,390	21.22	21 Feb	1981	760	70.86
30 Mar	1972	3,300	22.49	29 Apr	1911	744	72.14
13 May	1951	2,970	23.76	27 Mar	1957	720	73.41
12 Apr	1928	2,940	25.04	21 Jun	1973	710	74.68
10 Apr	1960	2,930	26.31	17 May	1967	700	75.95
30 Mar	1939	2,625	27.58	17 Apr	1924	698	77.23
21 Apr	1922	2,570	28.85	13 Apr	1908	644	78.50
5 May	1920	2,560	30.13	7 Apr	1980	640	79.77
20 Apr	1947	2,500	31.40	5 May	1935	612	81.05
3 Jul	1953	2,450	32.67	15 Mar	1945	470	82.32
18 Apr	1950	2,220	33.95	11 Mar	1968	450	83.59
28 May	1907	2,190	35.22	7 Jun	1929	430	84.87
1 Apr	1946	2,100	36.49	2 Apr	1962	360	86.14
4 Apr	1952	1,920	37.77	22 Mar	1934	328	87.41
18 Apr	1919	1,860	39.04	8 Jun	1932	260	88.68
7 Apr	1942	1,800	40.31	1 Apr	1910	207	89.96
8 Apr	1978	1,650	41.58	1 Jul	1926	194	91.23
20 Apr	1971	1,650	42.86	23 Mar	1961	155	92.50
2 Apr	1958	1,620	44.13	18 Apr	1940	137	93.78
30 Jun	1944	1,570	45.40	17 Apr	1937	90	95.05
27 Apr	1936	1,500	46.68	19 Apr	1977	90	96.32
4 Apr	1966	1,330	47.95	26 Jun	1915	41	97.60
29 Apr	1917	1,270	49.22	2 May	1931	8	98.87

(1) Data since 1936 - Estimated by Corps of Engineers for natural conditions without Lake Darling Dam.

(2) Estimated by Corps of Engineers from historical stage record.

Table A-11 -Plotting Points for Discharge Frequency, Floods of Record, Souris River at Minot, North Dakota (Partial-duration Series)

Natural Conditions (1)

Date	Year	Peak Discharge (cfs)	Weibull Plotting Position (percent)	Date	Year	Peak Discharge (cfs)	Weibull Plotting Position (percent)
	1882	22,800 (2)	0.99	20 Jun	1953	1,550	50.50
20 Apr	1904	12,000	2.12	27 Apr	1936	1,500	51.77
Apr	1976	11,800	3.39	15 Jun	1975	1,475	53.04
19 Apr	1969	10,000	4.67	14 Apr	1972	1,360	54.31
3 May	1979	9,250	5.94	4 Apr	1966	1,330	55.59
9 May	1975	8,100	7.21	21 Jul	1978	1,300	56.86
17 May	1948	7,900	8.49	12 Apr	1970	1,280	58.13
25 Apr	1974	6,000	9.76	29 Apr	1917	1,270	59.41
13 Apr	1943	5,700	11.03	20 Apr	1912	1,200	60.68
22 Apr	1955	5,400	12.31	8 Apr	1953	1,160	61.95
6 May	1916	4,260	13.58	31 Mar	1938	1,100	63.22
30 Apr	1927	3,900	14.85	13 Apr	1909	1,090	64.50
18 Apr	1956	3,700	16.12	10 Apr	1906	1,090	65.77
1 May	1970	3,560	17.40	4 Apr	1913	1,080	67.04
30 Apr	1923	3,460	18.67	20 Apr	1914	1,080	68.32
18 Apr	1925	3,450	19.94	17 Apr	1941	1,080	69.59
14 Apr	1949	3,390	21.22	11 Jun	1965	1,050	70.86
30 Mar	1972	3,300	22.49	19 Jun	1972	1,050	72.14
13 May	1951	2,970	23.76	6 Apr	1933	1,040	73.41
12 Apr	1928	2,940	25.04	19 May	1965	1,030	74.68
10 Apr	1960	2,930	26.31	9 Jun	1963	1,020	75.95
30 Mar	1939	2,625	27.58	8 Apr	1964	940	77.23
21 Apr	1922	2,570	28.85	14 Apr	1930	920	78.50
5 May	1920	2,560	30.13	20 Jun	1954	850	79.77
20 Apr	1947	2,500	31.40	21 Jul	1971	830	81.05
3 Jul	1953	2,450	32.67	10 Jul	1921	790	82.32
18 Apr	1950	2,220	33.95	27 Jun	1947	790	83.59
28 May	1907	2,190	35.22	30 Mar	1918	790	84.87
8 Apr	1951	2,110	36.49	25 Mar	1959	780	86.14
1 Apr	1946	2,100	37.77	21 Feb	1981	760	87.41
29 Jun	1976	2,100	39.04	29 Apr	1911	744	88.68
15 May	1955	2,030	40.31	27 Mar	1957	720	89.96
4 Apr	1952	1,920	41.58	21 Jun	1973	710	91.23
18 Apr	1919	1,860	42.86	17 May	1967	700	92.50
7 Apr	1942	1,800	44.13	17 Apr	1924	698	93.78
8 Apr	1978	1,650	45.40	26 Apr	1965	660	95.05
20 Apr	1971	1,650	46.68	13 Apr	1908	644	96.32
2 Apr	1958	1,620	47.95	7 Apr	1980	640	97.60
30 Jun	1944	1,570	49.22	5 Jul	1956	620	98.87

(1) Data since 1936 - Estimated by Corps of Engineers for natural conditions without Lake Darling.

(2) Estimated by Corps of Engineers fr[illegible] historical stage record.

Table A-12
Plotting Points for Discharge Frequency, Floods of Record,
Souris River near Verendrye, North Dakota (partial-duration series)

Existing Conditions

Date	Year	Peak Discharge cfs	Weibull Plotting Position (Percent)
19 Apr	1976	9,900	2.1
11 May	1979	6,000	4.3
30 Apr	1969	5,960	6.4
24 May	1975	5,510	8.5
8 Apr	1949	4,200	10.6
15 May	1970	3,700	12.8
18 May	1974	3,430	14.9
12 Apr	1951	2,710	17.0
16 Apr	1972	2,460	19.1
22 May	1948	2,300	21.3
2 May	1943	2,220	23.4
16 May	1950	2,150	25.5
7 Jul	1953	2,150	27.7
6 Apr	1952	2,050	29.8
24 May	1951	2,000	31.9
26 Apr	1955	1,970	34.0
30 Apr	1956	1,800	36.2
2 Apr	1971	1,600	38.3
2 Jul	1944	1,450	40.4
12 Aug	1962	1,380	42.6
13 Apr	1947	1,350	44.7
31 Mar	1978	1,300	46.8
30 Mar	1939	1,260	48.9
3 May	1947	1,220	51.1
16 Mar	1974	1,180	53.2
2 Apr	1960	1,180	55.3
21 Jun	1965	1,160	57.4
31 May	1953	1,140	59.6
31 Apr	1971	1,140	61.7
6 Apr	1942	1,100	63.8
17 Apr	1965	1,025	66.0
5 Jul	1976	1,000	68.1
5 May	1977	995	70.2
11 Jun	1963	992	72.3
30 Jul	1970	980	74.5
2 Apr	1958	960	76.6
19 Apr	1960	950	78.7
20 Jul	1969	870	80.9
22 Feb	1981	870	83.0
17 Jun	1972	870	85.1
6 Jun	1943	860	87.2
27 May	1972	850	89.4
4 Jul	1979	820	91.5
10 Jul	1971	800	93.6
26 Mar	1967	770	95.7
22 Jun	1964	660	97.9

of the existing condition frequency curves. The Verendrye partial duration curves for existing and natural conditions were used to drive the Velva frequency curves. The Verendrye natural conditions curve is shown on plate A-4.

32. Sawyer

Only one type of frequency curve, that for partial duration series instantaneous discharges, was prepared for the Souris River at Sawyer. Lacking stream records at Sawyer, the frequency curves for existing and natural conditions were obtained by interpolation between the Minot and Verendrye frequency curves, based on the primary contributing drainage areas. This is the same method as was used to develop the Velva frequency curve. Since the primary contributing drainage area at Sawyer (4,230 square miles) is only approximately 100 square miles less than at Velva, the Sawyer discharges are only slightly less than those at Velva. The Sawyer existing and natural conditions frequency curves are shown on plate A-5.

33. Velva

Only one type of frequency curve, that for partial duration series, instantaneous discharges, was prepared for the Souris River at Velva. Lacking streamflow records at Velva, the frequency curve was obtained by interpolation between Minot and Verendrye frequency curves. This was done by plotting discharges at selected frequencies from the Minot and Verendrye frequency curves on a logarithmic grid at the respective primary contributing drainage area (Minot = 3,900 square miles; Verendrye = 4,400 square miles). Straight lines were drawn at the selected frequencies to obtain discharge-drainage area-frequency relationships. Then, at the primary contributing drainage area for Velva (4,330 square miles), the discharges were obtained at various frequencies and were plotted as a discharge-frequency curve for Velva. Since the drainage area at Velva is approximately the same as that at Verendrye, the Velva discharges are only slightly less than those at Verendrye. The frequency curve, for existing conditions with Lake Darling Dam in operation, is included on plate A-5.

34. A frequency curve for natural conditions at Velva, without the Lake Darling Reservoir, was obtained by multiplying discharges from the Minot (100-year period, 1882-1981) natural frequency curve by 1.07. This factor was obtained by consideration of contributing drainage areas and the factor used for Verendrye. As in the case of the natural frequency curve for Verendrye, this curve was adjusted slightly to be consistent with the curve for existing conditions. The Velva natural frequency curve is shown on plate A-5.

35. Modified Conditions at Velva

The proposed 4-foot raise of Lake Darling was investigated by computer modeling to determine the effects of the project on the flows at Velva. Both synthetic floods and historic floods were used in the analysis. Historic

floods were used to calibrate the model and to estimate the local flows. Synthetic floods were developed and routed to aid in constructing the frequency curve, because the historic events did not cover a wide enough spectrum of rarer events. The largest flood of record, in 1976, was approximately a 2-percent exceedence frequency flood.

36. Volume-duration data for the gage at Sherwood, North Dakota, were obtained through the WATSTORE data base of the U.S. Geological Survey. The Regional Frequency Program was used to determine preliminary volume-duration frequency curves for this station. The instantaneous peak frequency curve was determined in accordance with Bulletin 17B. Because the year 1931 was dropped as a low outlier in that analysis, 1931 was dropped from the volume-duration data for better consistency. Both skews and standard deviations of the data were smoothed graphically by plotting them versus the mean logs of the several durations. The smoothed skews and standard deviations were then supplied to the Regional Frequency Program to obtain the final volume-duration frequency curves. The Regional Frequency Program was modified locally to handle up to ten durations in one run. Durations used were the instantaneous peaks, and the 1-, 3-, 7-, 15-, 60-, 90-, 120- and 183-day volumes.

37. Synthetic floods are those which are created by forming a typical or "pattern" hydrograph into the mold of parameters provided by the volume-duration frequency analysis. The pattern hydrograph is either a composite of actual hydrographs or one suggested by typical basin performance. Six levels of synthetic floods were developed for the analysis; these were the 10-percent, 5-percent, 2-percent, 1-percent, 0.5-percent and 0.2-percent exceedence frequency events. The Balanced Hydrograph Program was used to adjust the pattern hydrograph until it acquired the requisite shape. The adjusted hydrographs were successively smoothed by averaging and re-running them until the output hydrographs were sufficiently smooth for use.

38. Floods of 1979, 1976 and 1969 were used to obtain routing coefficients and local flows by use of the HEC-1 routing optimization routines. Muskingum coefficients were developed for routing the synthetic floods from Lake Darling to Minot and Verendrye.

39. The natural attenuation of peak flows from Sherwood to Minot makes it difficult to determine appropriate local flows for this reach. Graphical adjustment of the frequency curve was necessary to produce results consistent with known conditions.

40. The flow-frequency curve at Velva for the modified (post-project) condition is shown on plate A-6. The flow reductions at Lake Darling were adjusted and reduced in the downstream direction to arrive at a set of curves that is internally consistent, and consistent with the natural and existing condition curves.

41. <u>Bantry</u>

All of the streamflow records for the station on the Souris River near Bantry, which started in March 1937, are for existing conditions with Lake

Darling Dam in operation. An existing condition discharge-frequency curve was derived graphically using Weibull plotting positions for all peaks over 500 cfs in 46 years of record (1937-1981) near Bantry plus an estimate of the peak flow for 1936 based on records near Towner, for a total of 46 years. Only one type of discharge-frequency curve was derived and this was for partail duration series, mean daily discharges. A partial duration series was chosen because damages in this reach begin at about 500 cfs. The separation of the peaks was determined based on economics, with a period of 30-day separation of peaks during the months of April through September being the guide that was used. The 46-year curve for Bantry also shows the effect of Lake Darling regulation on larger floods. No data are available at Bantry for the extremely large floods of 1904 and 1882. The frequency curves for Bantry from 46 years of records were adjusted by means of the Minot 100-year frequency curves to be consistent with the period at Minot, including the very large floods. A comparison of peak flows for 46 years at Minot, Verendrye, and Bantry shows that peak flows generally increase from Minot to Verendrye, but usually decrease from Verendrye to Bantry. A further study of the Souris River peaks shows that some of the large floods would decrease only a small amount between Verendrye and Bantry and the upper end of the Bantry frequency curve would be slightly above the Minot 100-year curve and lower than the Verendrye 100-year curve. The upper end of the Bantry curve is drawn to be consistent with the Minot, Verendrye and Westhope curves. The remainder of the Bantry frequency curve was based on the best-fit of points for the 46-years of record adjusted to a 100-year period at Minot and also drawn to be consistent with the 100-year curve for Verendrye. The natural condition curve at Bantry has been estimated based on the difference between Verendrye and Bantry existing condition curves. The Bantry discharge-frequency curves for existing and natural conditions are shown on plate A-5 Plotting points are listed in table A-13 for this existing condition curve.

42. <u>Westhope</u>

Discharge records at the station on the Souris River near Westhope are available since July 1929. However, for development of discharge-frequency curves for existing conditions, only records since 1936 were used, when Lake Darling Dam and other fish and wildlife reservoirs were placed in operation. Discharge-frequency curves were derived graphically using Weibull plotting positions from 46 years of record (1936-1981). Only one type of discharge-frequency curve was derived for records near Westhope and this was for annual mean daily discharges. The 46-year existing condition curve for Westhope also shows a slight effect of Lake Darling and other fish and wildlife reservoirs on larger floods. No data are available at Westhope on the extremely large floods of 1904 and 1882. The frequency curve from 46-years of record was adjusted by means of the Minot existing 100-year frequency curve to be consistent with the period at Minot, including the very large floods. The upper end of the Westhope curve is drawn to be consistent with the Minot and Westhope curves. The remainder of the curve is based on best-fit of the plotting points for 46 years adjusted to the 100-year period at Minot, although the lower end of the frequency curve deviates from the plotting positions to be consistent with the curves at Minot, Verendrye and Bantry. The adjustment

Table A-13 - Discharge-Frequency, Floods of Record, Souris River near Bantry and near Westhope, North Dakota

Existing Conditions

Bantry (Partial-Duration Series)					Westhope (Annual Series)			
		Peak Discharge					Peak Discharge	
Date	Year	Mean Daily (cfs)	Instant. (cfs)	Weibull Plotting Position (Percent)	Date	Year	Mean Daily (cfs)	Instant. (cfs)
	1882	(1)	(1)	1.0		1882	(1)	(1)
Apr	1904	(1)	(1)	2.0	Apr	1904	(1)	(1)
23 Apr	1976	9,260	9,330	3.0	26 Apr	1976	12,400	12,600
17 May	1979	5,850	5,900	4.0	7 May	1975	6,600	6,700
25 May	1975	5,640	5,750	5.0	18 Apr	1949	6,300	6,400
4 May	1969	5,430	5,660	5.9	22 Apr	1969	6,200	6,300
13 Apr	1949	4,560	4,760	8.12	21 May	1979	5,830	5,900
22 May	1970	3,600	3,640	10.33	25 Apr	1974	5,590	5,610
22 May	1974	3,330	3,350	12.55	14 Apr	1955	3,430	3,500
24 Apr	1972	2,310	2,320	14.77	6 Jun	1970	3,110	3,120
23 Apr	1951	2,180	2,220	16.98	29 Apr	1951	3,100	3,100
7 Jun	1951	2,110	2,110	19.20	20 Apr	1972	3,050	3,060
31 May	1948	1,990	2,000	21,42	21 May	1956	2,930	3,040
15 May	1943	1,910	1,910	23.63	26 Apr	1948	2,900	2,900
4 May	1955	1,900	1,920	25.85	17 May	1950	2,630	2,650
23 May	1950	1,890	1,910	28.07	22 May	1943	2,240	2,240
17 Jul	1953	1,760	1,770	30.28	23 Apr	1960	2,040	2,120
10 May	1956	1,700	1,700	32.50	9 Jul	1944	2,000	2,000
5 Jul	1944	1,600	1,600	34.72	19 Apr	1947	1,800	1,800
14 Apr	1952	1,540	1,550	36.93	13 Jul	1954	1,760	1,780
18 Apr	1947	1,320	1,320	39.15	13 Aug	1953	1,540	1,550
11 May	1947	1,230	1,230	41.37	24 Apr	1952	1,420	1,420
10 May	1971	1,180	1,190	43.58	30 Apr	1971	1,340	1,350
9 Apr	1960	1,110	1,120	45.80	31 Mar	1945	1,040	1,040
25 Mar	1974	1,000	1,000	48.02	21 Apr	1942	1,000	1,100
10 Jul	1976	984	984	50.23	20 Apr	1967	853	889
25 Jun	1965	967	971	52.45	28 Jun	1965	850	864
15 Jun	1963	902	905	54.67	2 May	1966	846	850
8 Apr	1978	890	908	56.88	22 Apr	1978	778	846
4 Apr	1939	850	866	59.10	8 Apr	1946	600	600
14 Apr	1942	850	850	61.32	24 Jun	1963	530	600
26 Jul	1969	847	870	63.53	16 May	1964	518	518
11 Jun	1953	836	840	65.75	20 May	1973	438	444
Apr	1936	800(2)	800(2)	67.97	9 Nov	1957	367	367
22 Jun	1972	775	780	70.18	24 Apr	1981	330	426
24 Mar	1945	766	778	72.40	9 Sep	1968	277	292
4 Jul	1954	750	750	74.62	29 Apr	1980	250	284
26 Apr	1966	694	700	76.83	12 May	1958	202	563
31 Mar	1956	680	690	79.05	3 Jun	1959	162	187
3 Aug	1970	672	675	81.27	14 Apr	1936	139	139
13 Apr	1954	650	655	83.48	2 Oct	1977	128	135
20 Apr	1965	608	620	85.70	18 Jun	1938	42	51
1 Apr	1946	606	607	87.92	1 Oct	1961	29	30
12 May	1965	578	580	90.13	23 Oct	1940	27	29
7 May	1967	565	569	92.35	16 Jun	1939	26	27.5
12 May	1978	520	520	94.57	12 Jun	1941	25	36
13 May	1964	517	522	96.78	7 Aug	1962	25	208
15 Jul	1971	502	502	99.00	11 Apr	1937	9	9

NOTE: Instantaneous peaks are listed to show the small difference between mean daily and instantaneous peaks.

(1) Peaks not determined for historical floods.

(2) Estimated by Corps of Engineers from records near Towner.

of the plotting positions for the 46 years at Westhope to 100 years at Minot is similar to the procedure used at Minot, and are shown on table A-13 and plate A-5 . The natural condition curve at Westhope has been estimated based on the difference between Verendrye and Westhope, and Bantry and Westhope, existing condition curves. The natural and existing conditions curves are shown on plate A-5 . Plotting points are listed in table A-13 for the existing condition curve.

43. Gassman Coulee and Local Area above Minot

The hydrology for Gassman Coulee and for the local area between Foxholm and Minot is found in Supplement No. 1 to Design Memorandum No. 1, Flood Control, Burlington Dam, pages 1-8 and Exhibits 2 and 3.

44. VOLUME-FREQUENCY CURVES

45. General

Peak and volume-frequency curves were derived for the Souris River near Sherwood gaging station. The curves were derived by the analytical method of Leo R. Beard as described in the publication "Statistical Methods in Hydrology," January 1962.

46. Sherwood

The gaging station on the Souris River near Sherwood was selected for computation of volume-frequency curves to be transferred to the Lake Darling site because it is the nearest station above Lake Darling and because of its nearly equal primary contributing drainage area (3,173 square miles to 3,400 square miles at Lake Darling). Final volume-frequency curves were based on observed data for the years 1931 and 1933 through 1980. A lengthy and severe drought occurred over the basin in the years 1931 through 1940 and use of the records for 1932 would give undue weight to the dry years. The HECWRC program used for the instantaneous curve selected 1932 as a "low outlier" for the instantaneous curve, in accordance with WRC Bulletin 17B criteria. Thus 1932 was also dropped from the volume-frequency analysis for consistency. Observed flows are considered to represent both natural and existing conditions at Sherwood since the only regulation is by small dams in Canada. This limited regulation is considered negligible.

47. Volume-frequency curves were computed from 49 years of record (1931, 1933 through 1980) by the analytical method. The regional frequency program was used to statistically correlate and analyze volume information for peak flows plus nine durations. Both standard deviations and skews were smoothed and adjusted to be consistent both internally and with the HECWRC instantaneous curve. The adopted volume-frequency curves for Sherwood are shown on plate A-7

48. SYNTHETIC HYDROGRAPHS

48. Synthetic hydrographs were derived for the Sherwood gaging station using the adopted volume-frequency curves. The HEC Balanced Hydrograph Program

No. 23-J2-L237 was utilized to derive the hydrographs. The pattern hydrograph used was based on the typical shape of 1948, 1950, 1969, 1975, 1976, and 1979 hydrographs for the Souris River at Sherwood. The adopted synthetic hydrographs for the 10-, 5-, 2-, 1-, 0.5- and 0.2-percent chance floods are shown on plate A-8.

49. Lake Darling Dam

Synthetic hydrographs from Sherwood were routed to the Lake Darling Reservoir with incremental local flow. The percentage of local flow was based on the incremental drainage area. The local area runoff was assumed to run off some 3 to 10 days prior to the peak inflow at Sherwood. The amount and timing of the local flows was adjusted for each event to match as closely as possible the existing-condition frequency curve at Foxholm.

50. UNIT HYDROGRAPHS

51. General

Unit hydrographs were computed for use in the derivation of the probable maximum flood and standard project flood hydrographs at Lake Darling. Unit hydrographs were computed for the primary and secondary contributing drainage areas at four locations. These locations are the following:

- Souis River near Estevan, Saskatchewan
- Moose Mountain Creek near Oxbow, Saskatchewan
- Local area between Estevan, Oxbow and Sherwood
- Local area between Sherwood and Lake Darling Dam

Each unit hydrograph was peaked 25 percent for conservative results in accordance with EM 1110-2-1405, paragraph 25. The unit hydrographs and their derivations are described in the following paragraphs.

52. Souris River near Sherwood, North Dakota

A study of observed flood hydrographs at the gaging station near Sherwood shows considerable variation in the shapes of the hydrographs. This variation is due, to a considerable extent, to the effect of the amount and timing of the flow from the major tributary, Moose Mountain Creek, as it joins the Souris River near Oxbow, Saskatchewan. For this reason and because of the large size of the drainage area above the Sherwood gage, the total area was divided into three subareas for the purpose of deriving unit hydrographs. The subareas are: 1) Souris River near Estevan, Saskatchewan; 2) Moose Mountain Creek near Oxbow, Saskatchewan and; 3) the remaining area below Estevan and Oxbow to the Sherwood gage. Unit hydrographs were computed for floods of record, assuming that all of the flow comes from the primary drainage areas. Unit hydrographs were then computed for the secondary drainage areas but were used only for extremely large floods and with a reduced depth of runoff. The drainage areas used for the unit hydrographs are based on drainage areas determined for Design Memorandum No. 1 dated February 1973. The drainage areas were then updated for this study and a drainage area ratio applied to the unit hydrograph ordinates derived from D.M. No. 1. The original drainage areas and the adjusted drainage areas are shown in table A-14.

Table A-14 - Comparison of Adjusted Drainage Area

Gaging Station	Drainage Areas in Square Miles: Primary Previous	Primary Current	Secondary Previous	Secondary Current	Gross Previous	Gross Current
Souris River near Estevan, Sask.	1,562	1,612	2,914	2,397		
Moose Mountain Creek near Oxbow, Sask.	990	1,064	1,202	1,277		
Souris River near Sherwood, ND local drainage area between Oxbow and Estevan	497	497	657	657		
Non-contributing					1,120	1,120
Total					8,940	8,633

53. Only the flood hydrographs for the snowmelt seasons of 1948 and 1969 appeared to be suitable for unit hydrograph derivations. Unit hydrographs were derived for the primary drainage areas at the three locations from one or both of these floods. It is assumed that the runoff for these two floods was mostly generated in a period of 24 hours and was from the primary drainage area only. Unit hydrographs were then computed for the gross drainage areas by means of Snyder's coefficients and unit hydrographs were obtained for secondary areas by subtraction. As the runoff originating on the secondary areas must flow overland on these areas, which generally have no channels, and then over the primary contributing areas before reaching the Souris River channel, the unit hydrographs from the secondary areas were lagged 2 days to allow for the extra time of travel.

54. Souris River near Estevan, Saskatchewan

Flood hydrographs for April 1948 and for April 1969 were considered for deriving a unit hydrograph for the Souris River near Estevan, Saskatchewan. The flood which peaked on 24 April 1948, with a maximum mean daily flow of 7,580 cfs, was selected. Runoff depth for this flood averaged 1.51 inches on the primary drainage area. The unit hydrograph, assumed to be for a 24-hour duration of runoff, has a peak value of 4,950 cfs. It was adjusted from a 24-hour to a 12-hour unit hydrograph by the S-curve method. This adjustment increased the peak to 5,040 cfs.

55. Snyder's coefficients were computed for the 12-hour unit hydrograph for the primary contributing drainage area. They are: Ct = 12.34 and 640 Cp = 560. By means of these coefficients, a unit hydrograph was derived for the

Table A-15 - 12-Hour Unit Hydrographs for Selected Areas above Sherwood, N. Dak., Gaging Station

	Souris River Near Estevan, Sask.				Moose Mountain Creek near Oxbow, Sask.						Local Area above Sherwood, N. Dak.	
	Primary Area		Secondary Area		Primary Area	Secondary Area	Primary Area		Secondary Area		Primary Area	Secondary Area
Drainage Area (sq. mi.)	1562	Adj. 1612	2914	Adj. 2397	990	1202	990	Adj. 1064	1202	Adj. 1277	497	657
Flood Year	1948		1948		1948	1948	1969		1969		1948	1948
Time in Days	Discharge (cfs)				Discharge (cfs)		Discharge (cfs)				Discharge (cfs)	
0	0	0			0		0	0			0	
1/2	110	113			60		140	150			60	
1	220	227			150		275	295			170	
1 1/2	340	351			280		535	574			320	
2	450	464	0	0	450	0	1180	1266	0	0	600	0
2 1/2	570	588	340	280	820	10	3250	3486	0	0	1250	70
3	690	712	680	559	2490	50	4390	4709	25	26	1900	210
3 1/2	810	836	1010	831	6860	120	4260	4570	115	122	2240	480
4	920	949	1350	1110	6400	250	4000	4291	520	551	2190	940
4 1/2	1040	1073	1680	1382	4800	500	3750	4023	3000	3180	2110	1500
5	1170	1207	2010	1653	3860	1150	3500	3754	3790	4017	2010	2100
5 1/2	1300	1342	2340	1925	3200	2600	3220	3454	4400	4663	1900	2600
6	1500	1548	2680	2204	2730	7500	2910	3122	4410	4674	1790	2920
6 1/2	2070	2136	2990	2460	2380	7950	2580	2768	4350	4610	1660	2880
7	3020	3117	3350	2756	2100	6040	2220	2381	4230	4483	1520	2730
7 1/2	5040	5201	3840	3159	1860	4700	1880	2017	4080	4324	1380	2510
8	4800	4954	4550	3743	1650	3820	1600	1716	3840	4070	1220	2270
8 1/2	4410	4551	6180	5083	1460	3120	1410	1512	3500	3710	1040	2030
9	4040	4169	9040	7436	1300	2630	1260	1352	3080	3264	840	1820
9 1/2	3660	3777	9620	7913	1170	2320	1120	1201	2780	2946	640	1610
10	3310	3416	9000	7403	1060	2070	1010	1083	2480	2628	490	1390
10 1/2	2980	3075	8130	6688	940	1870	910	976	2190	2321	380	1190
11	2640	2724	7260	5972	820	1680	820	880	1890	2003	290	1020
11 1/2	2360	2435	6390	5256	720	1530	740	794	1620	1717	220	860
12	2140	2208	5590	4598	620	1390	660	708	1410	1494	160	720
13	1870	1930	4300	3537	470	1170	530	568	1050	1113	90	510
14	1700	1754	3640	2994	350	960	430	461	800	848	40	380
15	1540	1589	3130	2575	280	790	350	375	700	742	10	290
16	1400	1445	2760	2270	240	660	290	311	620	657	0	200
17	1270	1311	2460	2024	210	550	260	279	550	583		130
18	1160	1197	2200	1810	170	470	220	236	490	519		70
19	1070	1104	1990	1637	150	380	180	193	410	434		0
20	980	1011	1800	1481	130	320	140	150	350	371		
21	900	929	1610	1324	110	270	100	107	300	318		
22	800	826	1440	1185	90	220	75	80	260	276		
23	730	753	1320	1086	70	170	40	43	220	233		
24	660	681	1200	987	50	130	20	21	165	175		
25	580	599	1060	872	35	100	5	5	130	138		
26	500	516	910	748	20	80	0	0	90	95		
27	430	444	780	642	10	70			45	48		
28	360	371	650	535	0	50			0	0		
29	280	289	540	444		30						
30	210	217	410	337		0						
31	150	155	300	247								
32	90	93	210	173								
33	30	31	150	123								
34	0	0	110	90								
35			70	58								
36			0	0								
Totals*	84,000	86,766	156,720	139,824	53,250	64,805	53,220	57,093	64,700	68,647	26,730	35,340

*Totals include half day values which are not tabulated above beyond 12 days.

gross drainage area with a peak discharge of 14,660 cfs. The shape was influenced by the relative location of the primary and secondary drainage areas. Then, by subtracting the unit hydrograph of the primary drainage area, a unit hydrograph was obtained for the secondary drainage area. It has a peak value of 9,620 cfs. The unit hydrograph is given in table A-15 Drainage area ratios were then applied to the unit hydrograph ordinates. The adopted unit hydrographs for the primary and secondary drainage areas are shown in table A-15 and plates A-9 and A-10, respectively.

56. Moose Mountain Creek near Oxbow, Saskatchewan

Two unit hydrographs were drived for the primary contributing drainage area of Moose Mountain Creek near Oxbow, Saskatchewan. One unit hydrograph was derived from the flood which peaked on 21 April 1948 with a maximum mean daily flow of 3,060 cfs. This hydrograph had a fast rise and fall during the high flow portion of the flood. Surface runoff was 0.44 inch and the peak of the 24-hour unit hydrograph was 6,770 cfs. With adjustment to a 12-hour unit hydrograph by the S-curve method, the peak was increased to 6,860 cfs. The other unit hydrograph was derived from the flood which peaked on 10 April 1969 with a maximum mean daily flow of 3,980 cfs. This flood had a fast rise to the peak but the recession was considerably slower than that of the 1948 flood. The surface runoff of the 1969 flood was 0.92 inch on the primary drainage area and the 24-hour unit hydrograph peak was 4,330 cfs. With adjustment to a 12-hour unit hydrograph, the peak flow was increased to 4,390 cfs.

57. Unit hydrographs were computed for the gross drainage area (primary plus secondary areas) of Moose Mountain Creek by means of Snyder's coefficients. The coefficients for the 12-hour unit hydrographs of the primary drainage area were computed as follows: 1948 flood, Ct = 4.63 and 640 Cp = 540; 1969 flood, Ct - 3.89 and 640 Cp = 292. Assuming that the same coefficients apply to the gross drainage area, 12-hour unit hydrographs were constructed for the gross area. The peak values were 13,900 cfs for the 1948 unit hydrograph and 8,590 cfs for the 1969 unit hydrograph. The unit hydrographs for the primary drainage area were subtracted from the respective unit hydrographs for the secondary area. The respective peak values were 7,950 cfs and 4,410 cfs. The unit hydrographs are tabulated in table A-15. The 1969 flood hydrograph appears to be more representative of most floods of record than the 1948 flood and produced better reconstitution of observed flows near Sherwood; therefore, the 1969 unit hydrograph was used on Moose Mountain Creek for hypothetical flood computations.

58. A drainage area ratio was applied to the 1969 unit hydrographs ordinates for the primary and secondary drainage areas based on the updated drainage area analysis. The adopted unit hydrograph ordinates are tabulated in table A-15 and are shown on plates A-11 and A-12.

59. Local Area Between Estevan, Oxbow, and Sherwood

The flood of 1948 was selected for derivation of a unit hydrograph for the local area above the Sherwood gaging station. Discharge hydrographs for April and May 1948 on the Souris River near Estevan, Saskatchewan, and on Moose

Mountain Creek near Oxbow, Saskatchewan, were both routed down to the Sherwood, North Dakota, gaging station. The routed hydrographs were subtracted from the Sherwood hydrograph to obtain a hydrograph for the local primary contributing drainage area. The computed maximum mean daily flow from the local area was 3,510 cfs on 29 April.

60. A unit hydrograph was derived from the computed hydrograph of the local area. The unit hydrograph peak was 2,200 cfs and the hydrograph was computed from a runoff depth on the primary area of 1.58 inches. This unit hydrograph, assumed to be for a runoff duration of 24 hours, was adjusted to become a 12-hour unit hydrograph, which increased the peak flow to 2,240 cfs. A unit hydrograph was then derived for the gross local area by means of Snyder's coefficients. The coefficients, obtained from the unit hydrograph for the local primary drainage area, are: $C_t - 5.51$ and $640\ C_p = 369$. The peak discharge of the unit hydrograph for the gross area is 5,020 cfs. By subtraction of the unit hydrograph of the primary area from that for the gross area, a unit hydrograph was obtained for the secondary area. The peak discharge of the 12-hour unit hydrograph of the secondary area portion of the local area above Sherwood was 2,920 cfs. The unit hydrographs for both primary and secondary areas are included in table A-15 and are shown on plates A-13 and A-14.

61. Reconstitution of the 1969 Flood at Sherwood

The purpose of reconstitution of the 1969 flood at Sherwood, North Dakota, was to check the unit hydrographs derived for the Souris River at Estevan and Sherwood and for Moose Mountain Creek near Oxbow. This was done using the unit hydrographs derived based on the original drainage area and not the unit hydrographs developed with the new updated drainage areas. The 1969 flood period was used because it had the best available precipitation data for March and April 1969. Runoff from snowmelt was the primary cause of the flood, as an analysis of the precipitation data showed that no significant rainfall was recorded during March and early April. A water content map was made from snow surveys, dated 10-14 March, for the Souris River basin by the St. Paul District Corps of Engineers (Reservoir Regulating Section). This water content map, along with water equivalent of the snow on the ground data from the 14 March 1969 map published in NOAA Technical Report NWS13, was used as basic data for reconstitution.

62. Analysis of two large floods, the 1948 flood and the 1969 flood, shows that flood hydrographs at Sherwood have two peaks, the first created by runoff from the local drainage area and Moose Mountain Creek and the second peak created by runoff from the Souris River drainage area above Estevan including the Long Creek drainage area. Variation of the snowmelting conditions in these areas results in different values for the two peaks. The 1969 flood had a well-defined (high) first peak and a low second peak. The 1948 flood had a very low first peak and a high second; however, the poorly-defined first peak is known to exist by analysis of the 1948 flood hydrograph at Oxbow, upstream.

63. The reconsituted 1969 flood at Sherwood is shown on plate A-15 The shape is close to the observed flood, and the maximum instantaneous peak differs only by 4 percent from observed (12,400 cfs observed and 11,900 cfs computed). The smooth connection of the two peaks is the result of using only one local unit hydrograph for the Souris River drainage area between Estevan and Sherwood instead of two which are one for the area between Estevan and Oxbow and the other for the area between Oxbow and Sherwood. This was done for simplification in computations.

64. <u>Local Area between Sherwood and Lake Darling</u>

There are no accurate records of inflow between Sherwood and Burlington (or Lake Darling). This is because Lake Darling has affected all available discharge records to some extent. A synthetic procedure was used to develop unit hydrographs for the primary and secondary drainage areas between these two points. The procedure used is a dimensionless curvilinear unit hydrograph as developed by Mr. Victor Mockus and used extensively by the Soil Conservation Service (SCS).

65. The SCS lag (L) was determined by multiplying 0.6 times the time of concentration (Tc). Time of concentration was estimated to be the same for the primary and secondary drainage areas because of the longitudinal characteristic of this local area. It was estimated to be approximately 37 hours by using the Kirpich equation and an estimate of the celerity of the wave through Lake Darling. The unit duration according to SCS equations is approximately 5 hours; therefore, 5-hour unit hydrographs were derived.

66. The 5-hour unit hydrograph for the primary contributing drainage area (230 square miles) has a peak of 4,497 cfs and volume of 12,370 acre-feet. The 5-hour unit hydrograph for the secondary contributing drainage area (300 square miles) has a peak of 5,865 cfs and volume of 16,130 acre-feet. In flood routing studies, the secondary drainage area runoff was assumed to lag the primary drainage area runoff by 1 day. This was done to take into account the added distance to the main stem of the Souris River, the poorly defined drainage channels, and the large amount of depressional storage. The unit hydrographs were peaked 125% and are shown on plates A-16 and A-17.

67. This synthetic unit hydrograph method was used rather than Snyder's method because of ease of computation and the relative unimportance of exacting results. It is assumed to be reasonable in this case for the following reasons:

a. The unit hydrographs are used only to determine the contribution of the small local areas to the probable maximum flood at Lake Darling.

b. The local area will not contribute to the peak of the probable maximum flood at Lake Darling, but only add to the rising side of the hydrograph.

68. PROBABLE MAXIMUM PRECIPITATION AND SNOWMELT

69. Probable Maximum Precipitation

Probable maximum precipitation (PMP) for any drainage area located within the Souris River basin was obtained using procedures and data presented and described in the report, "Estimate of Probable Maximum Precipitation and Snowmelt Criteria for the Red River of the North and Souris River," dated December 1970, and prepared by the Hydrometeorological Branch, Office of Hydrology, National Weather Service. This report is defined within this design memorandum as the H.M. Report. Figure 3-2 of the H.M. Report gives enveloping depth-duration-area values of PMP for the center of the Red River of the North basin above Pembina for the all-season rainfall (defined as 15 June in the earlier reports of the Weather Service). Data obtained from figure 3-2 for any drainage area located within the Souris River basin was reduced by 10 percent (see page 10 of the H.M. Report). Precipitation depths are given for durations from 6 to 72 hours, varying by 6-hour periods. PMP data obtained from figure 3-2 were transformed into 6-hour incremental PMP values by successive subtraction, geographic adjustment and rearrangement of the sequence recommended by the H.M. Report.

70. For areas larger than 1,000 square miles, the two greatest PMP values were areally adjusted using isohyetal patterns for distribution of 6-hour PMP increments presented consecutively on figures 5-1, 5-2 and 5-3 of the H.M. Report. PMP data for 15 March, 31 March, and 15 April, were developed from the all-season basic PMP data by adjusting data for location, season and area. Geographic variations of PMP for the Souris River, for different seasons, are presented on figure 4-3a (March), 4-3b (April), and 4-3c (all-season) of the H.M. Report. Geographic adjustments relative to the center portion of the Souris River basin were determined by plotting the center of gravity of the drainage area under consideration of these maps. Seasonal adjustments are presented on table 4-2, page 15, of the H.M. Report. These are the same for all drainage areas.

71. Computation of the probable maximum flood at Lake Darling was, from a hydrologic point of view, divided into two parts; first, computation of the probable maximum flood hydrograph at Sherwood, and second, routing this hydrograph to Lake Darling Dam and combining it with the runoff from the local drainage areas between Sherwood and Lake Darling. The reason for such separation is the large difference between the two parts of the total drainage area above Lake Darling. The lower part is relatively small in comparison to the upper part, and includes Lake Darling which occupies a large part of its territory.

72. For the computation of the probable maximum precipitation above Sherwood, the gross drainage area was divided into three subdrainage areas: Areas 1, 2, and 3. Two additional areas were also considered and are included below.

a. Area 1 - Drainage area above Estevan including Long Creek, totalling 4,009 square miles.

b. Area 2 - Drainage area of Moose River Creek above Oxbow, totaling 2,341 square miles.

c. Area 3 - Drainage area between Estevan and Sherwood, totaling 1,154 square miles.

d. Area 4 - The gross drainage area above the Sherwood gage, which equals 7,504 square miles.

e. Area 4a - The total drainage area above the Souris River near Foxholm gage, which equals 9,470 square miles.

73. The all-season PMP data for the areas listed, as derived from the depth-duration-area curve (figure 3-2 of the H.M. Report) are presented in table A-16. In table A-16 the area 4 column represents the rainfall over the gross drainage area above Sherwood. It is included to define the residual rainfall over the remaining two areas when the PMP is centered over either Area 1, 2 and 3. The Area 4a column is included to give an indication of the PMP rainfall which could center over the total drainage area above the Burlington Dam.

Table A-16 - All-Season PMP Data for Drainage Areas 1, 2, 3, 4 and 4a

	Drainage Area				
	1	2	3	4	4a
Time in Hours	4,009 Sq. Mi. Inches	2,341 Sq. Mi. Inches	1,154 Sq. Mi. Inches	7,504 Sq. Mi. Inches	9,470 Sq. Mi. Inches
6	7.52	9.32	10.80	5.94	5.50
12	9.27	11.07	12.80	7.61	7.10
18	10.35	12.15	13.90	8.69	8.10
24	11.12	12.98	[illegible]	9.45	8.90
30	11.79	13.68	[illegible].50	10.13	9.60
36	12.42	14.28	16.10	10.76	10.30
42	13.00*	14.83*	16.60*	11.27*	10.80*
48	13.50	15.30	17.00	11.75	11.20
54	13.87*	15.72*	17.40*	12.13*	11.70*
60	14.22	16.08	17.80	12.51	12.10
66	14.55*	16.42*	18.20*	12.85*	12.40*
72	14.85	16.74	18.50	13.19	12.70

*These data have been extrapolated from a smooth curve plotting depth versus duration.

74. All data presented in table A-16 has been reduced by 10 percent. Data presented in table A-16 should be geographically, seasonally, and areally adjusted, as described above. Table A-17 presents geographic and seasonal adjustments for the drainage areas. Table A-18 presents PMP for these areas after tranforming them into 6-hour incremental PMP, rearranging them in the recommending sequence, and applying geographic, seasonal and areal adjustment.

Table A-17 - Geographic and Seasonal Adjustment for Areas #1, 2, 3, and 4a

	Geographic Adjustment				Seasonal Adjustment			
	All Season	15 March	31 March	15 April	All Season	15 March	31 March	15 April
Area #1	98.8	95.6	96.9	98.1	100.0	53.0	62.0	72.0
Area #2	99.3	97.6	98.3	99.0	100.0	53.0	62.0	72.0
Area #3	101.6	105.0	103.5	102.1	100.0	53.0	62.0	72.0
Area #4a	100.0	100.0	100.0	100.0	100.0	53.0	62.0	72.0

Table A-18 - Probable Maximum Precipitation for Areas 1, 2, 3, and 4a After All Adjustments

6-Hour Increment	Probable Maximum Precipitation in Inches															
	Area #1				Area #2				Area #3				Area #4a			
	All Season	15 March	31 March	15 April	All Season	15 March	31 March	15 April	All Season	15 March	31 March	15 April	All Season	15 March	31 March	15 April
8	0.50	0.26	0.30	0.30	0.47	0.24	0.29	0.34	0.40	0.22	0.25	0.29	0.40	0.21	0.29	0.29
6	0.57	0.29	0.35	0.41	0.55	0.29	0.34	0.39	0.40	0.22	0.25	0.29	0.70	0.37	0.43	0.50
5	0.66	0.34	0.40	0.41	0.70	0.36	0.43	0.50	0.70	0.38	0.44	0.51	0.70	0.37	0.43	0.50
7	0.62	0.32	0.38	0.44	0.60	0.31	0.37	0.43	0.60	0.33	0.38	0.43	0.50	0.27	0.31	0.36
4	0.76	0.39	0.46	0.74	0.83	0.43	0.51	0.60	0.90	0.49	0.57	0.65	0.80	0.42	0.50	0.58
2	1.62*	0.85*	0.99*	1.16*	1.59*	0.83*	0.98*	1.19*	1.85*	1.01*	1.17*	1.34*	1.50*	0.81*	0.94*	1.09*
1	6.48*	3.32*	3.94*	4.63*	6.43*	3.98*	4.70*	5.49*	9.88*	4.07*	6.25*	7.15*	5.00*	2.63*	3.06*	3.53*
3	1.07	0.55	0.65	0.77	1.08	0.56	0.66	0.78	1.10	0.60	0.69	0.80	1.00	0.53	0.62	0.72
9	0.36	0.18	0.22	0.26	0.42	0.22	0.26	0.30	0.40	0.22	0.25	0.29	0.50	0.27	0.31	0.36
10	0.35	0.18	0.21	0.25	0.36	0.19	0.22	0.26	0.40	0.22	0.25	0.29	0.40	0.21	0.25	0.29
11	0.33	0.17	0.20	0.24	0.34	0.18	0.21	0.24	0.40	0.22	0.25	0.29	0.30	0.16	0.19	0.22
12	0.29	0.15	0.18	0.21	0.32	0.17	0.20	0.23	0.30	0.16	0.19	0.22	0.30	0.16	0.19	0.22

*Data marked by asterisks are areally adjusted.

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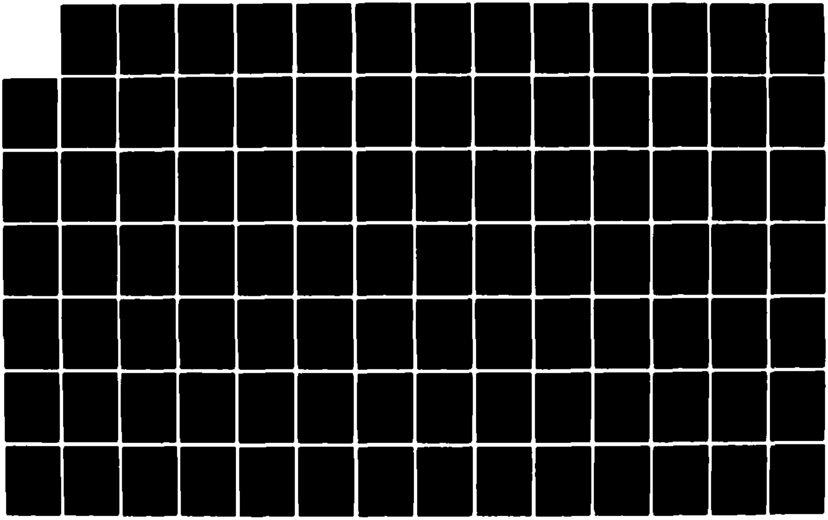

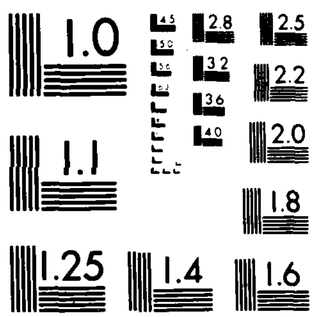

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75. Snowmelt

Snowpack data were obtained from figure 7-4 of the H.M. Report. As is shown in table A-19 the variation of the snowpack water equivalent is not as great as the rainfall depth.

Table A-19 - Variation in the Snowpack Water Equivalent Depth and Rainfall Depth with Drainage Area and Seasonal Changes

Season Time	Drainage Area (Sq. Mi.)	Snowpack Water Equivalent (Inches)	Water Equivalent (Inches)	Rainfall (Inches)	Rainfall (Inches)
15 Mar	9,470	6.80		6.41	
			0.80		1.73
	1,154	7.60		8.14	
31 Mar	9,470	5.30		7.48	
			0.80		3.46
	1,154	6.10		10.94	
15 Apr	9,470	3.40		8.66	
			0.40		3.89
	1,154	3.80		12.55	
All-Season	9,470	0		12.10	
			0		5.23
	1,154	0		17.33	

76. This permits an assumption that uniform distribution of the snow over the total drainage basin will be critical for PMP computations. In other words, for the snowmelt depth computations, the maximum snowpack water equivalent obtained for the total drainage area was used. Snowpack water equivalent depths for different seasons are shown on table A-20.

Table A-20 - Snowpack Water Equivalent for 15 March, 31 March and 15 April for Total Drainage Area

Date	Snowpack Water Equivalent (Inches)	Remarks
15 March	6.8	For 15 April, use 50 percent of
31 March	5.3	the 15 March water equivalent
15 April	3.4	(see page 38 of the H.M. Report).

77. Snowmelt was computed for a rain-free period and for an open, flat area. For snowmelt computation, equation (25), paragraph 4-08 of EM 1110-2-1406 (5 Jan 60), "Runoff from Snowmelt," was used. The equation is shown below:

$$M-k'(0.00508Ii)(1-a)+(1-N)(0.0212Ta'-0.84)+N(0.029Tc')+k(0.0084V)(0.22Ta'+0.78Td')$$ where:

M - is the snowmelt in inches per day.

k' - is the basin short wave radiation melten factor for horizontal area. It may be assumed equal to 1.0 (see paragraph 4-04, page 13, "Runoff from Snowmelt").

Ii - is insolation or solar radiation on horizontal surface in Langleys. The insolation was determined from figure 5 of the referenced EM for a latitude of 49.5°. A sunshine ratio of 60 percent for March and April was obtained from page 65 of the Climatic Atlas.

15 March - 315 langleys
31 March - 375 langleys
15 April - 440 langleys

a - snow surface albido was assumed equal to 47 percent.

N - cloud cover was taken from Climatic Atlas, page 71, and is equal to 0.7 for March, and 0.6 for April.

Ta' - is the difference between the air temperature measured at 10 feet and snow surface temperature.

Td' - is the difference between dewpoint temperature measured at 10 feet and the snow surface temperature.

Tc' - is the difference between the could base temperature and snow surface temperature.

k - the basin convection-condensation melt factor.

v - wind speed in mph at 50 feet above snow.

78. The snowmelt depth, as shown on table A- 21 represents snowmelt possibility under particular conditions which we are accepting as probable maximum snowmelt conditions. As shown, these snowmelt capabilities are higher than accepted snowpacks for 15 March, 31 March and 15 April. Corrected depths of the snowmelt water are shown on table A-22.

79. PROBABLE MAXIMUM RUNOFF

80. Losses

The ground is normally frozen for a considerable depth below the surface at the time of late winter or early spring snowmelt. Consequently, there is little loss of the snowmelt water. Initial losses are assumed to be zero for the snowmelt floods. During the late spring and summer initial losses will be taken up by the uniform loss rates before any runoff occurs. Of primary importance in computing the probable maximum runoff is the assumption of critical values for uniform loss rates. The uniform loss rate of 0.02 inch per hour for all snowmelting periods, 0.02 inch per hour for 15 and 31 March, 0.05 inch

Table A-21 - Temperature, Wind and Snowmelt Depth Preceding 15 March, 31 March and 15 April Storms

Days Before Storm	Air Temperature (F°) 15 March	31 March	15 April	Dew Point Temperature (F°) 15 March	31 March	15 April	Wind Speed (mph) 15 March	31 March	15 April	24-Hr. Snowmelt Depth (Inches) 15 March	31 March	15 April
10	30.6	36.6	42.2	21.6	27.6	33.2	10	10	10	0	0.585	1.328
9	30.6	37.6	42.2	22.1	29.1	33.7	10	10	10	0	0.728	1.361
8	31.6	37.6	42.2	23.9	29.9	34.5	12	12	12	0	0.774	1.485
7	31.6	37.6	42.2	24.6	30.6	35.2	13	13	13	0	0.879	1.518
6	32.6	37.6	43.2	26.3	31.3	36.9	13	13	13	0.156	0.939	1.826
5	34.6	38.6	44.2	29.0	33.0	38.6	14	14	14	0.471	1.153	2.091
4	36.6	40.6	46.2	31.6	35.6	41.2	15	15	15	0.644	1.535	2.515
3	37.6	43.6	47.2	33.3	39.3	42.9	15	15	15	1.043	2.060	2.736
2	41.6	49.6	53.2	37.9	45.9	49.5	18	18	18	1.880	3.402	4.140
1	51.6	58.6	61.2	48.6	55.6	58.2	31	31	31	5.621	7.724	8.590
Total										9.815	19.779	27.613

Table A-22 - Actual Snowmelt Preceding 15 March, 31 March and 15 April Storms

Days Before Storm	24-Hour Snowmelt Depth: 15 March Storm (Inches)	31 March Storm (Inches)	15 April Storm (Inches)
10	0	0.585	1.328
9	0	0.728	1.361
8	0	0.774	0.711
7	0	0.879	0
6	0.156	0.993	0
5	0.471	1.153	0
4	0.644	0.188	0
3	1.043	0	0
2	1.880	0	0
1	2.606	0	0
Total	6.800	5.300	3.400

per hour for 15 April and 0.15 inch per hour for the all-season rainfall period were used after careful analysis of unit hydrograph computations and the natural condition of the Souris River basin. After study of detailed maps, additional storage losses for depression storage totaling 5 inches were assumed for secondary contributing drainage aieas.

81. Snowmelt Runoff

It was assumed that the snowpack is dry at 32°F at the beginning of the snowmelt. The first portion of snowmelt is absorbed by the snowpack. In the computations, it is assumed that the snowpack will absorb melted water up to 10 percent of the water equivalent depth of the snow. Any additional snowmelt, plus the melted water contained in the snow that melts, becomes free water on the ground surface. After reduction by losses and transformation into 12-hour periods, the snowmelt available for runoff is shown on table A-23

Table A-23 - Snowmelt Excess for Application to Unit Hydrographs

	Snowmelt Runoff in Inches			
12-Hour Period	Before 15 March Storm	Before 31 March Storm	Before 15 April Storm	Before All-Season Storm
1	0	0	0	0
2	0	0	0	0
3	0	0	0.89	0
4	0	0	0.55	0
5	0	0.36	0.44	0
6	0	0.06	0.34	0
7	0	0.24	0	0
8	0	0.08	0	0
9	0	0.42	0	0
10	0	0.37	0	0
11	0	0.29	0	0
12	0	0.60	0	0
13	0	0.14	0	0
14	0	0	0	0
15	0.30	0	0	0
16	0.23	0	0	0
17	0.56	0	0	0
18	1.02	0	0	0
19	0.82	0	0	0
20	1.99	0	0	0
TOTAL	4.92	2.56	2.22	0.00

82. Rainfall Runoff

As shown on table A- 19 rainfall depth varies with the size of drainage area much more than snowmelt depth does. Consequently, for the drainage area above Sherwood, four possible cases were considered:

a. Case 1 - The center of the storm is assumed to be located at the center of the Souris River local drainage area between Estevan and Sherwood (which equals 1,154 square miles and is termed Drainage Area No. 3). Rainfall depth computed with this assumption is applied only for the primary and secondary contributing areas of Drainage Area No. 3. The difference between the total volume of the rainfall over Drainage Area No. 4 (gross drainage area above Sherwood) and the total volume of the rainfall over Drainage Area No. 3 is distributed uniformly over Drainage Areas No. 1 and 2.

b. Case 2 - The center of the storm is assumed to be located at the center of the Moose Mountain Creek basin above Oxbow (which equals 2,341 square miles and is termed Drainage Area No. 2). As in Case 1, rainfall depth computed with this assumption is applied only for the primary and secondary contributing areas of Drainage Area No. 2. The difference between the total volume of the rainfall over Drainage Area No. 4 and the total volume of the rainfall over Drainage Area No. 2 is distributed uniformly over Drainage Areas No. 1 and 3.

c. Case 3 - The center of the storm is assumed to be located at the center of the drainage basin above Estevan (which equals 4,009 square miles and is termed Drainage Area No. 1). The same procedure for distributing rainfall depths to the other areas was used in this case as was used in Cases 1 and 2.

d. Case 4 - The center of the storm is assumed to coincide with the center of the total drainage basin above Souris River near Foxholm gage (which equals 9,470 square miles and is termed Drainage Area No. 4a). Table A-24 shows rainfall excess data after losses are subtracted from probable maximum precipitation data and transformed to 12-hour periods.

83. Combined Snowmelt and Rainfall Runoff

Tables A-25 , A- 26 , A-27 and A-28 present combined probable maximum snowmelt and rainfall excess data for use with unit hydrographs. On these tables, probable maximum rainfall excess data are presented after having been adjusted in accordance with procedures as described above. Probable maximum combined rainfall-snowmelt excess for secondary contributing areas are derived by subtracting an additional 5 inches of storage loss from the excess value used for the primary contributing area.

84. All data on tables A-25 , A- 26 , A-27 and A-28 represent rainfall-snowmelt excess from the Souris River drainage area above Sherwood. For the Souris River drainage area between Sherwood and Burlington Dam, the rainfall was computed by estimating the average rainfall over the area with PMP centered over Moose Mountain Creek, together with the same snow depth as was used for the area above Sherwood as described in paragraph 75.

Table A-24 - Rainfall excess for application to unit hydrographs

12-hour period	Area #1 All Season	Area #1 15 March	Area #1 31 March	Area #1 15 April	Area #2 All Season	Area #2 15 March	Area #2 31 March	Area #2 15 April	Area #3 All Season	Area #3 15 March	Area #3 31 March	Area #3 15 April	Area #4 All Season	Area #4 15 March	Area #4 31 March	Area #4 15 April
	Probable Maximum Excess in Inches															
1	0.00	0.31	0.41	0.17	0.00	0.29	0.39	0.13	0.00	0.20	0.26	0.00	0.00	0.34	0.44	0.20
2	0.00	0.42	0.54	0.31	0.00	0.43	0.56	0.33	0.00	0.47	0.58	0.34	0.00	0.40	0.50	0.26
3	0.72	1.00	1.21	1.10	0.69	1.02	1.25	1.19	0.95	1.26	1.50	1.39	0.60	0.99	1.20	1.07
4	5.75	3.63	4.35	4.80	5.71	4.30	5.12	5.67	9.18	4.43	6.70	7.35	4.20	2.92	3.44	3.65
5	0.00	0.12	0.19	0.00	0.00	0.17	0.24	0.00	0.00	0.20	0.26	0.00	0.00	0.24	0.32	0.06
6	0.00	0.08	0.14	0.00	0.00	0.11	0.17	0.00	0.00	0.14	0.20	0.00	0.00	0.08	0.14	0.00
	6.47	5.56	6.84	6.38	6.40	6.32	7.73	7.32	10.13	6.70	9.50	9.08	4.80	4.97	6.04	5.24

Table A-25 - Total rainfall-snowmelt excess for application to unit hydrographs - 15 March

12-Hour Period	Case-1. Maximum Rain over Area #3: Area #3 Primary Area (Inches)	Area #3 Secondary Area (Inches)	Area #2 Primary Area (Inches)	Area #2 Secondary Area (Inches)	Area #1 Primary Area (Inches)	Area #1 Secondary Area (Inches)	Case-2. Maximum Rain over Area #2: Area #2 Primary Area (Inches)	Area #2 Secondary Area (Inches)	Area #1 Primary Area (Inches)	Area #1 Secondary Area (Inches)	Area #3 Primary Area (Inches)	Area #3 Secondary Area (Inches)	Case-3. Maximum Rain over Area #1: Area #1 Primary Area (Inches)	Area #1 Secondary Area (Inches)	Area #2 Primary Area (Inches)	Area #2 Secondary Area (Inches)	Area #3 Primary Area (Inches)	Area #3 Secondary Area (Inches)	Case-4. Maximum Rain Over #4a Areas #1, 2 & 3: Primary Area (Inches)	Secondary Area (Inches)
1-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0.30	0	0.30	0	0.30	0	0.30	0	0.30	0	0.30	0	0.30	0	0.30	0	0.30	0	0.30	0
16	0.23	0	0.23	0	0.23	0	0.23	0	0.23	0	0.23	0	0.23	0	0.23	0	0.23	0	0.23	0
17	0.56	0	0.56	0	0.56	0	0.56	0	0.56	0	0.56	0	0.56	0	0.56	0	0.56	0	0.56	0
18	1.02	0	1.02	0	1.02	0	1.02	0	1.02	0	1.02	0	1.02	0	1.02	0	1.02	0	1.02	0
19	0.82	0	0.82	0	0.82	0	0.82	0	0.82	0	0.82	0	0.82	0	0.82	0	0.82	0	0.82	0
20	1.99	0	1.99	0	1.99	0	1.99	0	1.99	0	1.99	0	1.99	0	1.99	0	1.99	0	1.99	0
21	0.20	0.12	0.29	0.21	0.29	0.21	0.29	0.21	0.28	0.20	0.28	0.20	0.31	0.23	0.24	0.16	0.24	0.16	0.34	0.26
22	0.47	0.47	0.42	0.42	0.42	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.42	0.42	0.44	0.44	0.44	0.44	0.40	0.40
23	1.26	1.26	0.88	0.88	0.88	0.88	1.02	1.02	0.91	0.91	0.91	0.91	1.00	1.00	0.86	0.86	0.86	0.86	0.99	0.99
24	4.43	4.43	2.56	2.56	2.56	2.56	4.30	4.30	2.27	2.27	2.27	2.27	3.63	3.63	1.78	1.78	1.78	1.78	2.92	2.92
25	0.20	0.20	0.14	0.14	0.14	0.14	0.17	0.17	0.14	0.14	0.14	0.14	0.12	0.12	0.19	0.19	0.19	0.19	0.24	0.24
26	0.14	0.14	0.12	0.12	0.12	0.12	0.11	0.11	0.12	0.12	0.12	0.12	0.08	0.08	0.17	0.17	0.17	0.17	0.08	0.08
	11.62	6.62	9.33	4.33	9.33	4.33	11.24	6.24	9.07	4.07	9.07	4.07	10.48	5.48	8.60	3.60	8.60	3.60	9.98	4.89

Table A-26 - Total rainfall-snowmelt excess for application to unit hydrographs -31 March

12-Hour Period	Case-1. Maximum Rain over Area #3						Case-2. Maximum Rain over Area #2						Case 3. Maximum Rain over Area #3						Case-4. Maximum Rain over Area #4a	
	Area #3		Area #2		Area #1		Area #2		Area #1		Area #3		Area #1		Area #2		Area #3		Areas #1,2 & 3	
	Primary Area (Inches)	Secondary Area (Inches)	Primary Area (Inches)	Secondary Area (Inches)	Primary Area (Inches)	Secondary Area (Inches)	Primary Area (Inches)	Secondary Area (Inches)	Primary Area (Inches)	Secondary Area (Inches)	Primary Area (Inches)	Secondary Area (Inches)	Primary Area (Inches)	Secondary Area (Inches)	Primary Area (Inches)	Secondary Area (Inches)	Primary Area (Inches)	Secondary Area (Inches)	Primary Area (Inches)	Secondary Area (Inches)
1-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0.36	0	0.36	0	0.36	0	0.36	0	0.36	0	0.36	0	0.36	0	0.36	0	0.36	0	0.36	0
6	0.06	0	0.06	0	0.06	0	0.06	0	0.06	0	0.06	0	0.06	0	0.06	0	0.06	0	0.06	0
7	0.24	0	0.24	0	0.24	0	0.24	0	0.24	0	0.24	0	0.24	0	0.24	0	0.24	0	0.24	0
8	0.08	0	0.08	0	0.08	0	0.08	0	0.08	0	0.08	0	0.08	0	0.08	0	0.08	0	0.08	0
9	0.42	0	0.42	0	0.42	0	0.42	0	0.42	0	0.42	0	0.42	0	0.42	0	0.42	0	0.42	0
10	0.37	0	0.37	0	0.37	0	0.37	0	0.37	0	0.37	0	0.37	0	0.37	0	0.37	0	0.37	0
11	0.29	0	0.29	0	0.29	0	0.29	0	0.29	0	0.29	0	0.29	0	0.29	0	0.29	0	0.29	0
12	0.60	0	0.60	0	0.60	0	0.60	0	0.60	0	0.60	0	0.60	0	0.60	0	0.60	0	0.60	0
13	0.14	0	0.14	0	0.14	0	0.14	0	0.14	0	0.14	0	0.14	0	0.14	0	0.14	0	0.14	0
14-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0.26	0	0.38	0	0.38	0	0.39	0	0.35	0	0.35	0	0.41	0	0.29	0	0.29	0	0.44	0
22	0.58	0	0.56	0	0.56	0	0.56	0	0.56	0	0.56	0	0.54	0	0.59	0	0.59	0	0.50	0
23	1.50	0	1.09	0	1.09	0	1.25	0	1.11	0	1.11	0	1.21	0	1.07	0	1.07	0	1.20	0
24	6.70	6.60	2.83	2.42	2.83	2.42	5.12	4.88	2.73	2.31	2.73	2.31	4.35	4.07	2.13	1.64	2.13	1.64	3.44	3.14
25	0.26	0.26	0.21	0.21	0.21	0.21	0.24	0.24	0.21	0.21	0.21	0.21	0.19	0.19	0.26	0.26	0.26	0.26	0.32	0.32
26	0.20	0.20	0.18	0.18	0.18	0.18	0.17	0.17	0.18	0.18	0.18	0.18	0.14	0.14	0.23	0.23	0.23	0.23	0.14	0.14
	12.06	7.06	7.81	2.81	7.81	2.81	10.29	5.29	7.70	2.70	7.70	2.70	9.40	4.40	7.13	2.13	7.13	2.13	8.60	3.60

Table A-27 - Total rainfall-snowmelt excess for application to unit hydrographs-15 April

12-Hour Period	Case-1. Maximum Rain over Area #3 — Area #3 Primary Area (Inches)	Area #3 Secondary Area (Inches)	Area #2 Primary Area (Inches)	Area #2 Secondary Area (Inches)	Area #1 Primary Area (Inches)	Area #1 Secondary Area (Inches)	Case 2. Maximum Rain over Area #2 — Area #2 Primary Area (Inches)	Area #2 Secondary Area (Inches)	Area #1 Primary Area (Inches)	Area #1 Secondary Area (Inches)	Area #3 Primary Area (Inches)	Area #3 Secondary Area (Inches)	Case-3. Maximum Rain over Area #1 — Area #1 Primary Area (Inches)	Area #1 Secondary Area (Inches)	Area #2 Primary Area (Inches)	Area #2 Secondary Area (Inches)	Area #3 Primary Area (Inches)	Area #3 Secondary Area (Inches)	Case-4 Maximum Rain over Area #4a Areas #1,2 & 3 Primary Area (Inches)	Case-4 Secondary Area (Inches)
1-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0.89	0	0.89	0	0.89	0	0.89	0	0.89	0	0.89	0	0.89	0	0.89	0	0.89	0	0.89	0
4	0.55	0	0.55	0	0.55	0	0.55	0	0.55	0	0.55	0	0.55	0	0.55	0	0.55	0	0.55	0
5	0.44	0	0.44	0	0.44	0	0.44	0	0.44	0	0.44	0	0.44	0	0.44	0	0.44	0	0.44	0
6	0.34	0	0.34	0	0.34	0	0.34	0	0.34	0	0.34	0	0.34	0	0.34	0	0.34	0	0.34	0
7-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0.13	0	0.13	0	0.13	0	0.10	0	0.10	0	0.17	0	0.03	0	0.03	0	0.20	0
22	0.34	0	0.34	0	0.34	0	0.33	0	0.34	0	0.34	0	0.31	0	0.38	0	0.38	0	0.26	0
23	1.39	0	0.97	0	0.97	0	1.19	0	0.97	0	0.97	0	1.10	0	0.94	0	0.94	0	1.07	0
24	7.35	6.30	3.01	1.67	3.01	1.67	5.67	4.54	2.86	1.49	2.86	1.49	4.80	3.60	2.11	0.68	2.11	0.68	3.65	2.40
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Σ	11.30	6.30	6.67	1.67	6.67	1.67	9.54	4.54	6.49	1.49	6.49	1.49	8.60	3.60	5.68	0.68	5.68	0.68	7.40	2.40

Table A-28 - Total rainfall excess for application to unit hydrographs - all season storm

12-Hour Period	Case 1. Maximum Rain over Area #3 — Area #3 Primary Area (Inches)	Area #3 Secondary Area (Inches)	Area #2 Primary Area (Inches)	Area #2 Secondary Area (Inches)	Area #1 Primary Area (Inches)	Area #1 Secondary Area (Inches)	Case 2. Maximum Rain over Area #2 — Area #2 Primary Area (Inches)	Area #2 Secondary Area (Inches)	Area #1 Primary Area (Inches)	Area #1 Secondary Area (Inches)	Area #3 Primary Area (Inches)	Area #3 Secondary Area (Inches)	Case 3. Maximum Rain over Area #1 — Area #1 Primary Area (Inches)	Area #1 Secondary Area (Inches)	Area #2 Primary Area (Inches)	Area #2 Secondary Area (Inches)	Area #3 Primary Area (Inches)	Area #3 Secondary Area (Inches)	Case-4 Maximum Rain over Area #4a Areas #1,2 & 3 Primary Area (Inches)	Case-4 Secondary Area (Inches)
1-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0.95	0	0.56	0	0.56	0	0.69	0	0.59	0	0.59	0	0.72	0	0.49	0	0.49	0	0.60	0
24	9.18	5.13	3.24	0	3.24	0	5.71	1.40	3.50	0	3.50	0	5.75	1.47	1.94	0	1.94	0	4.20	0
25-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10.13	5.13	3.80	0	3.80	0	6.40	1.40	4.09	0	4.09	0	6.47	1.47	2.43	0	2.43	0	4.80	0

85. PROBABLE MAXIMUM FLOODS

86. Probable Maximum Flood-Sherwood

Design Memorandum No. 1, dated February 1973, investigated 16 cases for computation of the probable maximum flood (PMF) hydrograph as Sherwood. In each case, PMF hydrographs were computed for primary and secondary drainage areas of the Souris River and Long Creek at Estevan, Moose Mountain Creek at Oxbow and Souris River between Estevan and Sherwood. The PMF hydrographs were developed by applying rainfall-snowmelt excess amounts to the computed unit hydrographs. Routing and combining of these developed flood hydrographs was accomplished by use of the "Flood Forecasting" computer program 723-GI-F5040. Routings constants were developed from an investigation of the 1948 and 1969 runoff events. Hydrographs computed for Estevan and Oxbow were combined and routed to Sherwood and then combined with hydrographs computed for the local area above Sherwood.

87. Design Memorandum No. 1 presented the computed hydrographs and maximum daily peaks for the various dated storms and various maximum rainfall locations. The most critical case for the PMF at the Sherwood gaging station was the 15 March storm with maximum rainfall over Moose Mountain basin above Oxbow, Drainage Area No. 2 (Case 2). Snowmelt runoff and rainfall runoff for the 15 March storm also gave the maximum runoff volume. Therefore, Case 2 precipitation and snowmelt excess was applied to the adopted unit hydrographs.

88. For this study, drainage areas upstream of the Sherwood gaging station were updated and the ordinates of the previous unit hydrographs were adjusted. The 1948 and 1969 flood events are relatively minor flood events compared to the probable maximum flood. The unit hydrographs applicable to the most intense period of rainfall during the design storm would be expected to have a higher peak discharge ordinate, and would represent a higher concentration of runoff than might be indicated by the unit hydrograph derived from the 1948 and 1949 flood events. Therefore, the unit hydrographs were peaked 25- and 50-percent higher to assure conservative results. Because of the large number of sloughs and potholes in the basin, the unit hydrographs that were peaked 25-percent higher appeared reasonable and were adopted for the design flood computation.

89. The runoff hydrograph for the Souris River at Estevan for the primary, secondary, and total area is shown in plate A-18. The Estevan hydrograph was then routed and combined with the primary and secondary hydrograph on Moose Mountain Creek at Oxbow. Plate A-19 shows the primary, secondary, routed and total hydrographs at this location. The Oxbow hydrograph was then routed and combined with the primary and secondary hydrographs generated by the local area between Sherwood, Oxbow and Estevan. Plate A-20 shows these hydrographs. The probable maximum flood at the Sherwood gage has a peak discharge of 92,800 cfs and volume of 2,742,700 acre-feet.

90. Table A- 29 shows the routing constants used in this analysis.

Table A-29 - Travel Times and Routing Constants - Souris River

Location	Travel Time (days)	Routing Constants (12-Hr.) Lag	No. of Routing Values Averaged
Estevan to Oxbow	4	7	15
Oxbow to Sherwood	1	2	3
Sherwood to Lake Darling	1	1	2

91. STANDARD PROJECT FLOOD

No detailed standard project flood studies were developed for the large drainage area above the site of Lake Darling. The standard project flood was selected as a percentage of the probable maximum flood. According to paragraph 2-03 of EM 1110-2-1411, the standard project flood (SPF) based on detailed studies, usually equals 40 to 60 percent of the probable maximum flood (PMF). The engineer manual also states that 50 percent is considered representative of average conditions.

92. Because of the small percentage of the total drainage area that normally contributes to runoff, the Souris River basin above Sherwood is not considered an average basin. The amount of drainage area contributing runoff to floods is somewhat proportional to the size of the flood. The secondary drainage area contributing runoff to the SPF at Sherwood is probably some factor less than the drainage area contributing to PMF. It is also reasonable to assume that losses due to infiltration, depressional storage, etc., will be of a somewhat larger percentage for the SPF. Furthermore, the SPS rainfall data obtained from EM 1110-2-1411 generally averages about 40 percent of the PMP data obtained from the H.M. Report referred to in paragraph 69. There is a remote possibility of critical timing of peaks at the junction of Moose Mountain Creek and the Souris River near Oxbow. Because of these factors, the peak discharge and volume of the SPF was selected to be 45 percent of the PMF.

93. Plate A-21 shows the SPF at Lake Darling relative to the PMF. It has a peak discharge of 44,600 cfs and volume of 1,459,000 acre-feet. Plate A-22 shows the inflow and outflow SPF through the proposed Lake Darling project.

94. ADOPTED SPILLWAY DESIGN FLOOD - LAKE DARLING

The adopted spillway design flood for Lake Darling is the Sherwood probable maximum flood for the 15 March probable maximum rainfall and snowmelt conditions, assuming the rainfall is centered over Moose Mountain Creek, plus an additional amount of runoff from the area between Sherwood and Lake Darling. The runoff from the area between Sherwood and Lake Darling was computed by estimating the average rainfall over the area, with the probable maximum precipitation centered over Moose Mountain Creek, together with the snow depth equal to that used above Sherwood. The precipitation excess was applied to the unit hydrographs that were peaked 125%. The primary contributing drainage area (230 square miles) yields a peak runoff of about

16,000 cfs five and one-half days after the start of snowmelt. The secondary drainage area (300 square miles), after 5 inches of initial loss, yeilds a peak runoff of about 20,100 cfs, six and one-half days after start of snowmelt. The probable maximum flood at Sherwood was transferred directly to Lake Darling Dam without attenuation. Time of travel from Sherwood to Lake Darling, under natural conditions, is about 1 day. The adopted spillway design flood has a peak value of 99,800 cfs and a volume of 2,918,000 acre-feet. Plate A-23 shows the inflow PMF hydrograph at Lake Darling. Plate A-24 shows the inflow and outflow PMF hydrograph through the proposed Lake Darling project.

95. CAPABILITY OF EXISTING LAKE DARLING TO PASS SPILLWAY DESIGN FLOOD (PMF)

The adopted spillway design flood of 99,800 cfs was routed through Lake Darling Dam to determine the capability of the existing structure. Three modes of failure were examined, as well as "no-failure." For the probable maximum flood, all available storage was filled in all cases about 4 days before the peak arrived. The dam is overtopped, in every case, by a flood of this magnitude. It is possible, but considered unlikely that failure of the structure would not occur. Breaches were assumed to occur in about 6 hours time, be rectangular in shape, and to be cut down to elevation 1585.

96. A summary of failure modes for the probable maximum flood, and the pertinent results are shown in table A-30 below. The resultant outflows were routed to Minot by normal-depth storage routing through 10 representative reaches.

Table A-30 - Probable Maximum Flood Failure Mode Summary

Breach Width	Type	Pool Elevation at Start of Breach	Maximum Elevation Reached	Maximum Outflow	Flow at Minot
1) 78 feet	Minimal, early	1603.6	1608.0	99,400	99,200
2) 200 feet	Average	1605.6	1606.6	98,900	98,900
3) 400 feet	Large, late	1607.5	1607.7	165,000	141,000
No failure		-	1608.8	99,400	99,300

97. The three modes of failure were selected as: 1) minimal breach (3 times height of dam) that would occur at the minimum elevation likely to cause failure: 2) a larger breach, about 7.5 percent of the dam crest length, occurring when the top of the dam was overtopped along approximately 600 feet of its length; 3) a large failure, 15% of dam crest, occurring only after

entire dam is overtopped by 1.5 feet of water. This last case is considered less likely than the other two modes of failure, and constitutes an extreme case of large breach at a high storage. For the other cases, the failure or non-failure of the dam does not affect the peak flow at Minot. However, the higher the pool at the time of failure, and the larger the breach, the faster the rate of rise of outflows from Lake Darling. This is offset somewhat by the 2-3 days warning provided by a nearly empty pool at the outset of the flood, which is considered reasonable for a spring snowmelt PMF. Attenuation due to channel storage enroute to Minot is essentially nil.

98. RESERVOIR

99. Reservoir Capacity

Lake Darling, with the authorized 4-foot raise, will provide additional flood control storage capacity for the protection of downstream damage centers. The flood control storage capacity at full pool, elevation 1605.0 is about 213,000 acre-feet, which would store about 0.75 inch of runoff from the 3,400 square mile primary drainage area. The area and capacity data for the reservoir were obtained from U.S. Geological Survey topographic maps and from Lake Darling Reservoir information obtained from the U.S. Fish and Wildlife Service. Lake Darling area-capacity curves are shown on plate A-25. Because Lake Darling is an existing water supply reservoir, a certain amount of capacity is not available for flood control storage. This capacity is estimated to be about 75,500 acre-feet at Lake Darling pool elevation 1594.0.

100. Sedimentation

Only limited data exist on sedimentation rates within the Souris River basin. However, using available information on drainage areas, existing upstream reservoir capacities and reservoir sedimentation rates based on observations at Baldhill and Homme Reservoirs in North Dakota, the 100-year sediment allocation in Lake Darling was estimated. The available information indicates that upstream of Lake Darling are seven reservoirs (all in Canada). Of the 3,400 square miles of contributing drainage area at Lake Darling, about 2,900 square miles are above these reservoirs. No detailed information is readily available as to the age, condition, operating methods or present sediment storage of these reservoirs. Without any special plan for passing sediment at these reservoirs, the total volume would be available for sediment storage during their useful life. A sediment trap efficiency of 90% and an average annual sediment yield of 0.3 acre-foot per square mile of contributing drainage area are assumed. Thus expected sediment yield per year is calculated as follows:

Above reservoirs in Canada:	2,900 x 10% x 0.3 =	87 acre feet/year
Below reservoir and above Lake Darling:	500 x 100% x 0.3 =	150 acre feet/year
		237 acre feet/year
Trap efficiency at Lake Darling	x	0.90
		213 acre feet/year

101. For a useful life of 100 years, this would amount to a sediment allocation of 21,300 acre-feet. If deposited 100% in the conservation pool, this would fill the reservoir to approximately elevation 1584.

102. HYDRO-METEOROLOGICAL DATA NETWORK

The collection and distribution of hydrologic data in the Souris River basin are complex tasks involving at least 13 governmental agencies in the United States and Canada. As the Souris flows from Saskatchewan, through the United States and into Manitoba, transfer of hydrologic data is also generally in the downstream direction. Data collection is outlined below as applicable to the United States portion of the Souris basin. For further information, see the "Souris River Basin Streamflow Forecasting and Inter-jurisdictional Liaison Handbook" by the Souris River Flow Forecasting Liaison Committee, Souris River Board of Control.

103. Saskatchewan - Water Survey of Canada operates the stream gaging network in Saskatchewan, collecting data from 27 gages on the Souris River and tributaries. Atmospheric Environment Service (AES) of Environment Canada operates the meteorological surveys for Saskatchewan, collecting data from 15 stations. Saskatchewan Department of the Environment (SDOE) operates the snow surveys, collecting data from 20 snow courses in early February, early and mid-March, and early April. Data collected by these agencies are reported to interested agencies in the United States and Manitoba, generally by telephone and with confirmation by mail.

104. United States - The National Weather Service (NWS) and its offices collect the basic meteorological data used in forecasts from 32 stations in North Dakota. The U.S. Geological Survey (USGS) operates gages at 22 stations, including six on the main stem of the Souris. The U.S. Fish and Wildlife Service (FWS) supplies data on levels at Lake Darling Dam. Snow Surveys are done by the NWS and the Corps of Engineers (USCE). The NWS also does snow surveys by aerial gamma-radiation survey, usually at times to coincide with surface data collections for calibration purposes.

105. The only U.S. gage on the Souris upstream of Lake Darling is located at Sherwood. Records and reliability are good, but travel time to the reservoir is relatively short, (about 2 days during high flows). Lack of adequately accurate and reliable data upstream of Sherwood is a limiting factor in the present operation of Lake Darling during flood periods. After the raise of Lake Darling, this information will be even more critical to proper flood-control operations.

106. The limited flood-control storage available in Lake Darling makes it necessary to have timely and accurate inflow information. The computer models which were run for this analysis assumed 72 hours of foresight for inflows. A reduction in the amount of foresight would significantly reduce the flood control performance of Lake Darling Dam. For this reason, the additional real-time gages in Canada are an essential part of the Lake Darling flood control plan.

107. In order to provide information to U.S. agencies in time for proper forecasting for Lake Darling, several Canadian gages will have to be converted to real-time reporting into the GOES satellite system of the National Oceanographic and Atmospheric Administration (NOAA), from data collection platforms (DCP) at the gage sites. The sites required to be converted are:

a. Moose Mountain Creek at Oxbow
b. Souris River at Glen Ewen
c. Souris River at Roche-Percee

108. Local gage readers should be hired to obtain check data weekly, and to provide readings by telephone in case of equipment failure. Two other DCP gages are needed, as follows:

d. Moose Mountain Creek at #9 Highway, south of Carlyle.
e. Souris River, either downstream of Dead Lake (first choice) or near Halbrite (second choice).

109. These five gages would provide enough additional data for the NWS River Forecast Center, FWS and the Corps of Engineers to make timely forecasts of inflow volumes at Lake Darling.

110. For pre-flood drawdown of Lake Darling, sufficiently early information is required to start drawdown by 1 March. This is required because of downstream constraints on winter flow changes, and relatively low release rates required. Since snow surveys take several days to accomplish, and aerial gamma surveys take about a week to analyze data by computer, sufficient lead-time must be allowed for in planning drawdown. The present early February-early March sequence leaves a significant gap where information is most needed. An additional snow survey is needed in February to provide input for March 1. It is suggested that the "early March" survey be moved up to late February, to provide timely input for drawdown of Lake Darling. As the later survey results are posted in mid-March, the progress of drawdown can be reanalyzed and modified as necessary to compensate for changes in the snowpack. The data network required for Gassman Coulee is described in the main report. Plate A-2 shows the weather and river gaging stations.

111. OPERATION PLAN FOR LAKE DARLING FOR FLOOD CONTROL

112. Objectives

The general operating plan is based on coordinating the operation of the Lake Darling with the flow from the uncontrolled drainage area to prevent discharge at the Minot control gage from exceeding 5,000 cfs. This plan of operation was determined from the following considerations and objectives:

a. Provide maximum downstream flood protection consistent with environmental and fish and wildlife considerations in the storage areas.

b. Reduce pool level below elevation 1600 as soon as possible after flood.

c. Attempt to attain elevation 1596.0 above Lake Darling Dam when spring runoff is completed.

d. Attempt to reduce the outflow from Lake Darling to 2,500 cfs by 15 May and to 500 cfs by 1 June.

e. For mid-summer rainstorm runoffs, flow through Minot should not exceed 500 cfs.

113. Forecasts

In practice, the operation of the Lake Darling Dam would be based on information obtained from rated discharge gages and other data located as follows:

a. The Souris River near Sherwood, North Dakota.

b. The Des Lacs River at Foxholm, North Dakota.

c. The Souris River at Minot, North Dakota.

d. The Souris River at Glen Ewen, Saskatchewan.

e. The Souris River at Roche-Percee, Saskatchewan.

f. Moose Mountain Creek at Oxbow, Saskatchewan.

g. Snow surveys and precipitation data gathered from stations located throughout the basin, including the Canadian portions.

114. Operation Plan - General

The general operation plan consists of three phases:

a. Pre-flood Lake Darling spring drawdown phase - Drawdown of the Lake Darling pool prior to a given flood event is an integral part of the overall operating plan. Lake Darling pool drawdown is the first step in the operating plan and is important because the extent of pool drawdown has a direct relationship to the amount of storage available for flood control. Drawdown is dependent upon the forecast 30-day spring snowmelt-runoff volume at Sherwood, the rate of drawdown, and the time available for drawdown between 1 March and spring breakup to accomplish drawdown. For any predicted flood, and for any height of conservation pool, releases will be made during the winter as required to achieve a pool elevation at or below 1596.0 on 1 March. For 30-day flood-volume predictions less than 50,000 acre-feet, no further drawdown is required. For volumes between 50,000 and 150,000 acre-feet, the amount of drawdown is roughly proportional to the additional predicted volume. Maximum drawdown is to elevation 1591.0, for all predicted volumes above 150,000 acre-feet (see plate A-26). The rate of

drawdown would be reviewed and adjusted on a regular schedule as the winter progresses, to ensure that the pool will be at or below the target elevation by 1 April.

b. Storage Phase - Maximum releases from Lake Darling are determined by a consideration of local inflow between the dam and Minot, and the use of the curve in plate A- 27 . This curve represents a plot of the predicted 30-day flood volume at Sherwood versus the peak target flow at Minot. The development of the curve was based primarily on past operation of Lake Darling Dam. This plan of operation was fully coordinated with the U.S. Fish and Wildlife Service. Sherwood inflow translated to Lake Darling would be released with possibly additional flow in order to meet the Lake Darling drawdown criteria previously discussed and presented in plate A- 26 This operation would be maintained until releases equalled target flow minus the local flow between Lake Darling and Minot. Thereafter, the Lake Darling release would be the Minot peak target flow minus the downstream local flow. Example: If the predicted 30-day flood volume were 130,000 acre-feet (as in the year 1955), the target drawdown elevation would be 1592.2 (from plate A-26 and the Minot peak target flow would be 2,000 cfs (plate A- 27). Lake Darling releases would initially be the Sherwood inflow translated to Lake Darling with possibly additional flow to meet drawdown criteria. This operation would be maintained until releases equalled the Minot peak target flow (2,000 cfs in this case) minus local flow between Burlington and Minot. The Lake Darling release would now be the Minot peak target flow of 2,000 cfs minus the downstream local flow.

c. Post-Peak Flood Storage Release Phase - After the peak stage has been reached in the reservoir, target releases are maintained until the pool has returned to conservation level, with the following exceptions in priority order:

(1) If after June 1st, 500 cfs or less if maintained.

(2) If above pool elevation 1600, target flow is maintained at Minot until below elevation 1600.

(3) If after May 15th and before June 1st, target flow is maintained to conservation pool, but not to exceed 2500 cfs release from Lake Darling.

115. Significant Spring and Summer Rainfall

If significant rainfall occurs during the spring or summer flood recession, the operating plan provides for discharging rainfall runoff when the criteria is based on following the unregulated flow recession. All rainfall inflow is discharged until the unregulated flow recession reaches 500 cfs. After this time, all rainfall runoff which would cause flows in excess of 500 cfs at Minot would be stored, but not to exceed pool elevation 1600. (Des Lacs flow could at times cause flows higher than 500 cfs at Minot.)

116. STREAMFLOW ROUTINGS - HISTORIC FLOODS

Six selected floods of record (1948, 1969, 1974, 1975, 1976 and 1979 were routed from Sherwood through the Lake Darling Reservoir downstream to Minot, Verendrye, Bantry and Westhope, North Dakota, using the Hydrologic Engineering Center generalized computer program HEC-5, "Simulation of Flood Control and Conservation Systems" dated April 1982.

117. Recorded flows at Sherwood were increased by various percentages, as shown in table A-31 to account for the increase in drainage area between Sherwood and the damsite. These increased flows were then translated to the reservoir as inflow using an appropriate travel time as shown in table A-32. Flood flow travel times between Sherwood and the damsite were estimated by analyzing travel times for various floods of record. Table A-31 was developed by considering periods of significant flood flow for each historical flood. By comparing for each period the Sherwood flood volume translated to Lake Darling with the Lake Darling Reservoir releases, as measured at Foxholm and the change in Lake Darling storage, the volume of reservoir inflow attributable to the uncontrolled drainage area between Sherwood and Lake Darling was obtained. The volume of this uncontrolled drainage area flow was then expressed as a percentage of Sherwood flood volume for each period.

Table A- 31 - Uncontrolled and Drainage Area Flow Contribution between Sherwood and the Lake Darling-Burlington Reservoir as a Percent of Recorded Sherwood Flow for Various Years

Year	1948	1969	1974	1975	1976	1979
	0.0	7.6	11.8	6.0	6.0	6.0

118. Reservoir inflow was routed through the reservoir in accordance with the reservoir operating plan. The resulting reservoir releases for the nine floods of record were utilized in streamflow routings accomplished using the progressive average-lag method, as described in paragraph 5-03 of EM 1110-2-1408. Flood flow travel times and routing constants were optimized for every reach of each individual flood of record using the routing parameter optimization feature of the Hydrologic Engineering Center generalized computer program 723-X6-L2010, "HEC-1 Flood Hydrograph Package," dated January 1973. Table A- 32 contains, in summary form, the optimized travel times and routing constants used in all historical flood routings. Local inflow hydrographs above Minot, Verendrye, Bantry and Westhope were developed to account for flow contributions from the uncontrolled drainage areas above these points. Reservoir releases were then progressively routed downstream, with local flow being added to the routed flow at each downstream point, resulting in modified condition discharge hydrographs at each downstream point. Existing and modified condition discharge hydrographs at Minot, Verendrye, Bantry and Westhope for the six selected floods of record are shown in plates A-28 through A-33.

Table A-32 Optimized Travel Times and Routing Constants
Souris River Basin

Year (1)	Location (2)	Travel Time (days) (3)	Lag (4)	No. of Routing Values Averaged (5)
	SOURIS RIVER			
1948	Sherwood, North Dakota			
	Foxholm, North Dakota	2	(reservoir routing used)	
	Minot, North Dakota	1	1	2
	Verendrye, North Dakota	4	4	6
	Bantry, North Dakota	4	4	2
	Westhope, North Dakota	7	7	10
1969	Sherwood, North Dakota			
	Foxholm, North Dakota	4	(reservoir routing used)	
	Minot, North Dakota	1	1	2
	Verendrye, North Dakota	5	5	9
	Bantry, North Dakota	5	5	2
	Westhope, North Dakota	6	6	2
1974	Sherwood, North Dakota			
	Foxholm, North Dakota	2	(reservoir routing used)	
	Minot, North Dakota	1	1	2
	Verendrye, North Dakota	5	5	10
	Bantry, North Dakota	7	7	10
	Westhope, North Dakota	7	7	7
1975	Sherwood, North Dakota			
	Foxholm, North Dakota	2	(reservoir routing used)	
	Minot, North Dakota	1	1	2
	Verendrye, North Dakota	4	4	2
	Bantry, North Dakota	5	5	2
	Westhope, North Dakota	6	6	2
1976	Sherwood, North Dakota			
	Foxholm, North Dakota	2	(reservoir routing used)	
	Minot, North Dakota	1	1	2
	Verendrye, North Dakota	4	4	2
	Bantry, North Dakota	3	3	2
	Westhope, North Dakota	6	6	10
1979	Sherwood, North Dakota			
	Foxholm, North Dakota	1	(reservoir routing used)	
	Minot, North Dakota	1	1	1
	Verendrye, North Dakota	2	2	2
	Bantry, North Dakota	6	6	1
	Westhope, North Dakota	5	5	10
Avg. Flood	Sherwood, North Dakota			
	Foxholm, North Dakota	3	(reservoir routing used)	
	Minot, North Dakota	1	1	2
	Verendrye, North Dakota	4	4	6
	Bantry, North Dakota	5	5	6
	Westhope, North Dakota	6	6	7

119. MODIFIED FREQUENCY CURVES

120. General

Discharge-frequency curves have been prepared for several locations along the Souris River showing the peak reduction effects of the proposed Lake Darling 4-foot raise. The Lake Darling Dam (Dam 83) is located on the Souris River approximately 20 miles northwest of Minot, North Dakota. The modified frequency curves are shown with the discharge-frequency curves for existing conditions on plate A-36 and are described in the following paragraphs.

121. Foxholm and Minot

The modified frequency curves at Foxholm and Minot were derived from peaks of synthetic floods routed through the modified Lake Darling structure. The peak outflows from Lake Darling were used directly for the Foxholm curve. These flows were then routed to Minot, and the peaks were plotted to obtain a modified curve. However, this curve gives only the contribution of the Souris River at Minot. So the frequency curves for the Des Lacs River at Foxholm and for the local area above Minot (including Gassman Coulee) were added to that for the Souris to obtain the total modified frequency curve at Minot, shown on plate A-6.

122. Downstream Damage Points

For the points along the Souris River downstream of Minot, 10 historic events were used to estimate the modified frequency curves. These historic events were routed from Minot to Verendrye, Bantry and Westhope. The plotting points for these floods were re-ordered and plotted to determine the modified frequency curves at Verendrye, Bantry and Westhope. The curves for Sawyer and Velva were interpolated between Minot and Verendrye according to the differences in drainage area and the estimated contribution of local flows.

123. RESERVOIR EFFECTS ON HYPOTHETICAL FLOODS

The spillway design flood (probable maximum flood) was routed through Lake Darling Reservoir to determine the maximum pool elevation and the resultant required top-of-dam. The initial pool elevation was assumed to be normal conservation pool, elevation 1596.0. For floods of this magnitude, there is no significant reduction of the peak flows since the available storage in the reservoir is used up about 5 days before the peak arrives. One benefit to downstream residents is a delay in the rising limb of the hydrograph of about 3 days. This delay would give time for notification and evacuation of residents in the floodplain. The pool reaches a maximum elevation of 1609.0. Plate A-24 shows the inflow/outflow hydrographs and pool elevation for the probable maximum flood routed through Lake Darling.

124. The standard project flood was also routed through Lake Darling, as shown on plate A-22. The pool elevation was assumed to be 1596.0 at the beginning of the flood. The delay in the rising limb of the hydrograph for downstream locations is 4 days.

125. SYNTHETIC FLOOD ROUTINGS THROUGH LAKE DARLING

Synthetic floods at Sherwood were routed through Lake Darling to estimate the peak flows downstream and to optimize the operational plans. The local flows between Sherwood and the dam were estimated as a percentage of Sherwood flows based on the local drainage area. This local flow was assumed to peak slightly ahead of flows at Sherwood since normally it would melt first. The inflow, outflow and reservoir elevations for the 20-, 33-, 50-, 100- and 200-year synthetic floods are shown on plates A-40 through A-44.

126. ELEVATION-DURATION AND PEAK STAGE FREQUENCY CURVES

Elevation-duration-frequency curves were developed for Lake Darling Reservoir for the 20-, 33-, 50-, 100- and 200-year synthetic floods. The synthetic floods were routed through the reservoir in accordance with the proposed plan of operation. Since variation in the timing of the peak with respect to May 15 has an effect on the curves for the larger flood events, the flood peaks were set to occur on April 15 for comparison. The elevation-duration curves for the above synthetic floods are shown on plate A-45.

127. Peak stage frequency curves were developed for Lake Darling Reservoir for both the existing and modified conditions. For floods more frequent than the 5-percent frequency, the maximum reservoir level is variable, depending on the plan of operation. The peak-stage frequency curves are shown on plate A-46.

128. RESERVOIR SPILLWAY

129. General

Lake Darling is classified as large in size and high in hazard potential; therefore, the spillway design flood (SDF) is the probable maximum flood (PMF). The PMF routed through the dam at full pool will result in a maximum pool elevation of 1609 assuming the reservoir is operated according to criteria set forth in EM 1110-2-3600, "Reservoir Regulation" with an induced surcharge pool envelope curve and 4 feet of induced surcharge pool storage. The reservoir spillway will consist of a gated ogee crest and a stilling basin designed in accordance with criteria in the now draft EM 1110-2-1603 manual. A plan and profile of the reservoir spillway and outlet works are shown in plates A-34 and A-35.

130. Crest

A gated spillway is proposed for Lake Darling to provide adequate outflow capacity for the spillway design flood without reaching a pool level which will create excessive surcharge storage, create backwater into Canada and produce excessive costs for the embankment of the dam. The gated spillway will consist of five tainter gates each 43 feet wide and 22 feet high. The gates will control discharge over a concrete low ogee section with crest at elevation 1584. The top of gates will be at elevation 1606 and the top of flood control pool will be at elevation 1605. The shape of the crest was designed in accordance with Miscellaneous Paper H-73-5, "Spillway Crest Design" by U.S. Army Engineer Waterways Experiment Station and will have an upstream face sloping at 45 degrees. Plate A-36 shows a detail drawing and corresponding tables for the crest geometry. The total length of the crest is 255 feet which includes five bays at 43 feet wide and four piers 10 feet wide. The pier nose shape will be Type III as per HDC Chart 111-5. Design head on the crest will be 21 feet which results in a weir coefficient of 3.88. During the SDF, the crest will be partially submerged, resulting in a 2-percent reduction in the C value (3.80). The C correction for submergence was determined from Figure 252, "Design of Small Dams" by the Bureau of Reclamation. The spillway rating curve with all four conduits in operation is shown in plate A-25 and includes the effect of tailwater submergence. Assuming one tainter gate is inoperable during the SDF, the reservoir shall reach a maximum pool elevation of 1612.6 which is 1.4 feet below top of dam elevation.

131. Stilling Basin

Plate A-37 and A-35 shows the plan and profile of the proposed stilling basin. The spillway stilling basin will be of reinforced concrete with a horizontal floor, parallel vertical side walls, two rows of baffle blocks and a 45 degree sloping end sill. The design of the basin is in accordance with the present draft EM 1110-2-1603 manual. The stilling basin was designed for a discharge of 99,800 cfs and corresponding tailwater elevation of 1598.3. Head loss over the crest was assumed to be 10 percent of the velocity head. Based on this assumption, the entrance velocity and depth would be 40 feet per second and 9.7 feet, respectively. The hydraulic jump will be weak with an entering design flow having a Froude number of 2.3. The stilling basin floor elevation was set at $(1.0)(d_2)$ or 26.80 feet below tailwater elevation. The length of stilling basin will be 80 feet which is four times the conjugate depth for the standard project flood. The height of baffle blocks will be approximately equal to $d_2/6$ or 4.5 feet. End sill height is 2.2 feet or one-half the height of baffle blocks. The face of the upstream row of baffle blocks was set at 40'0" downstream from the toe of the basin (1.5 d_2). The second row of baffle blocks will be located 11 feet downstream of the upstream face of the first row of baffle blocks (2.5 times the height of baffle block). Stilling basin side walls will provide 3 feet of freeboard above the tailwater elevation of 1598.3. The relationship of the conjugate depth curves to tailwater rating curves is shown on plate A-25.

132. RESERVOIR OUTLET WORKS

133. General

The hydraulic features of the reservoir outlet works were designed in accordance with EM 1110-2-1602, "Hydraulic Design of Reservoir Outlet Works." The outlet works shall consist of four rectangular galvanized steel conduits 4 feet high, 3 feet wide and 90 feet long. The conduits shall be used to pass low flows and sediment through the reservoir. Plates A-37 and A-35 show the plan and profile of the sluice. Plate A-36 shows the geometry and detail of the sluice intake.

134. Sluice

Each sluice shall be encased inside a 10-foot diameter pier. The sluice shall slope in a straight line from the intake to the outlet portal. The sluices and piers shall terminate at the upstream end of the stilling basin or downstream toe of the crest. An area reduction at the exit portal with flared side wall shall be provided to aid in horizontal spreading of the sluice jet and improve stilling basin performance.

135. The sluice intake shall be flared horizontally and vertically with a simple elliptical shaped curve as shown on HDC Chart 211-1, 1/1. The maximum upstream invert elevation at the downstream end of the flare section is 1573.00, and the downstream invert elevation is 1571.50. A trash rack shall be provided at each sluice inlet to protect against debris damage and clogging.

136. Each pier shall contain two 4-foot by 4-foot rectangular wet wells. The upstream well shall contain a 3-foot by 4-foot sluice gate that will regulate the flow. The gates shall be operated by hydraulic cylinders mounted at the top of the pier over the wet well. The cylinders shall be capable of remote control. The wet wells shall provide entrance and access to the sluice gate and stem of the hydraulic cylinder as well as to satisfy

high air demand. The upstream well shall contain a similar emergency gate so that if a service gate is inoperative in any position, closure of the gate passage can be made with the emergency gate for any pool level. Maximum head to the center line of the sluice intake shall be 34 feet.

137. The sluices were designed to pass a total discharge of 1,200 cfs at conservation pool elevation 1596.00. The sluice rating curve for pressure flow conditions is shown in plate A-38 and was determined by using WES Corps computer program H2044 "Discharge in a Rectangular Conduit." The Manning formula option was used with a Manning's "n" value of 0.013 and minor loss coefficient of 0.58. The rating for the sluice was developed assuming no submergence.

138. The four sluices should provide enough discharge capacity so that unnecessary vibration will not occur on the spillway tainter gates when the sluices are operating for low flows and additional capacity is required of the tainter gates. One spillway tainter gate 1 foot open would discharge 800 cfs at top of conservation pool. Assuming one sluice was inoperable, the remaining sluices would discharge 100 cfs more than this value. If one-half the number of sluices were assumed inoperable or two sluices out of service, the remaining sluices would have a discharge capacity of 600 cfs or 200 cfs less than 1 foot of tainter gate opening.

139. Outlet Work Stilling Basin

The sluices are designed to discharge into the spillway energy dissipator. The stilling basin was designed in accordance with the draft EM 1110-2-1603. Details are presented in the Spillway Stilling Basin section.

140. Outlet Channel

A preformed scour hole will be constructed beyond the end sill of the stilling basin so that flow can expand and dissipate its excess energy in turbulence rather than in a direct attack on the channel boundaries. Velocity over the end sill for the PMF will be approximately 15 fps. According to HDC Chart 712-1, the W_{50} and D_{50} size will be 2,800 pounds and 3.2 feet, respectively. Riprap this size is not available at reasonable cost; therefore the preformed scour hole shall be placed in concrete for a distance of 10 d_2 downstream of the upstream end of stilling basin or 270 feet. An 80-foot transition section will be provided with riprap thickness of 24 inches and minimum W_{50} of 41 pounds. The outlet channel shall then be lined with riprap at 12 inch thickness and minimum W_{50} of 17 pounds. Design velocities for the probable maximum flood shall approach 9 pfs at the toe of the 3:1 trapezoidal channel. The channel will be 460 feet wide with an average velocity of 8 fps. Channel riprap was sized in accordance with EM 1110-2-1601 and ETL 1110-2-120. During very low discharges, the channel invert will be submerged, thus precluding the use of a pilot channel to convey flow. Plate A-39 shows a typical cross section of the outlet channel.

W A T E R   Q U A L I T Y

WATER QUALITY

141. LAKE CLASSIFICATION

The state of North Dakota classification for Lake Darling is 2C - a cool water fishery with waters capable of supporting growth and propagation of non-salmonid fishes and marginal growth of salmonid fishes and associated aquatic life. The present value of the lake for fishery and recreation, coupled with the trophic state, is a lake that is presently somewhat degraded and progressing toward further degration.

142. LAKE MORPHOMETRY

At normal pool elevation of 1596.0, Lake Darling has a surface area of 9,900 acres, a mean depth of 11.1 feet, a maximum depth of 25.9 feet, a volume of about 112,000 acre-feet, and a mean hydraulic retention time of 1.4 years based on outflow. The lake is approximately 27 miles long (USEPA, 1976).

143. THERMAL REGIME

Lake Darling is a shallow reservoir and is expected to have a consistent pattern of weak and intermittent thermal stratification for the months of May through August. The preceding is based on stratification patterns observed at Lake Darling in 1974 (USEPA, 1976) and other reservoirs in North Dakota with similar morphometry. These reservoirs are Mt. Carmel Lake (USGS, 1981), Jamestown Reservoir (Peterka, 1981) and Lake Ashtabula (Peterka, 1969; Megard, 1980; and USGS, 1981).

144. If Lake Darling were to develop a strong and extended period of thermal stratification when operated under the proposed flood control plan, anoxic conditions would develop in the hypolimnion and water quality would be affected. A complete analysis of the water quality would then be required. If the thermal regime would not change significantly, little or no change in the water quality would be expected and the water quality in the reservoir would remain essentially as is.

145. MODEL DESCRIPTION

The thermal model used for this study, CE-THERM-R1, is derived from the water quality model CE-QUAL-R1. This model was developed by the Environmental Laboratory, Waterways Experiment Station, and is a direct descendant of the model, Water Quality for River-Reservoir Systems (WQRRS). WQRRS was developed for the Hydrologic Engineering Center by Water Resource Engineers, Inc., in 1974. The model is one-dimensional, which means that the reservoir is represented by a series of completely mixed horizontal layers. Longitudinal and lateral variations in constituents cannot be simulated. The model also assumes that the dynamics of each physical and chemical component can be described by the principle of conservation of mass.

Density of water is assumed to be a function of temperature and suspended and dissolved solids.

146. SELECTION OF STUDY YEAR

The study year selected for this study was 1976. The principal reason for selecting 1976 is that the proposed modified operation of Lake Darling would exhibit a significant change from historical operation in terms of high reservoir stages and duration of flood storage. The flood of 1976 was nearly equivalent to the once in 50-year recurrence interval flood.

147. In addition, water quality data for 1976, including temperature, are available for the Souris River at Sherwood, North Dakota, upstream of the reservoir and at Foxholm, North Dakota, downstream of the reservoir. There are no reservoir temperature data for Lake Darling for 1976 which could be used for direct calibration of the model.

148. INPUT DATA PREPARATION

Meteorological data were obtained from the Class A National Weather Service Station at Bismarck, North Dakota, which is located 120 miles south of the reservoir. The data included cloud cover, dry-bulb and dew-point temperatures, barometric pressure and wind speed. Precipitation data were obtained from the station at Foxholm, North Dakota, which is about 8 miles from the reservoir. Evaporation data were obtained from Williston Experimental Farm which is about 95 miles west of the reservoir.

149. Inflow data were obtained from USGS records for the Souris River at Sherwood, North Dakota, and adjusted to account for the intervening watershed between Sherwood and the dam.

150. Outflow data for simulation of the historical case were obtained from the USGS gage at Foxholm. Outflow data for simulation of the modified operation were obtained from the HEC-5 reservoir routings.

151. Daily inflow water temperature and total dissolved solids data were obtained from the data record at Sherwood, North Dakota.

152. COEFFICIENT SELECTION

As previously noted, there are no reservoir temperature data for Lake Darling for 1976 which could be used for direct calibration of the model. Therefore, coefficients within the ranges of values that have given satisfactory results in other similar studies were selected. The simulation runs using this initial set of coefficients are referred to as "control" runs because they provided the reference against which the sensitivity of specific coefficients were evaluated. Table 1 lists the parameter values and coefficients that were selected.

153. MODEL SENSITIVITY

Several sensitivity runs were made using different values for four CE-THERM-R1 model coefficients. These coefficients were SURFAC, EXTINS, SHELCF and EXCO, and are the ones which would be normally adjusted to calibrate the model to simulate an observed condition. Comparison of these sensitivity runs with the control runs showed some slight variations but were not considered significant enough to invalidate the selection of the initial values of the coefficients.

154. RESULTS OF STUDY

Figures 1 through 8 show graphically the results of the thermal model study using the coefficients and parameters listed in table 1.

a. Figure 1 shows the reservoir pool elevation comparison of the historical and proposed operation of Lake Darling for flood control. The greatest difference in pool elevation occurs roughly from mid-April through mid-June. From July through the fall, the modified flood control operational plan remains slightly above the historical elevation.

b. Figures 2 and 3 are time-history plots of surface and bottom temperature for the historical and modified operating plans, respectively. The plots show a pattern of weak, intermittent stratification.

c. Figure 4 compares the heat distribution in the water column for the two operating conditions during a brief period of stratification on 3 June and is representative of those for other periods of stratification. The surface to bottom temperature differential is about 5°C in both cases, but the average temperature of the water column is slightly cooler under the modified operation.

d. Figure 5 is a comparison of surface water temperature for both conditions. Temperature is essentially unaffected by the modified operation.

e. Predicted release temperatures for the 1976 historical condition are compared with measured temperatures at the Foxholm gage on figure 6. The Foxholm gage is about 14 miles downstream of the dam. The predicted water temperature of the release water is generally lower, but some warming would be expected due to shallower depths and increased exposure to atmospheric conditions in the river reach between the outlet of the dam and the gage.

f. Total dissolved solids (TDS) are generally considered to be a conservative parameter and were investigated to determine the dilution effects of reservoir storage. Figure 7 shows simulated outflow dissolved solids concentrations for historical conditions as compared to measured inflow of total dissolved solids concentrations. The reservoir has a substantial dampening effect on the concentrations. Figure 8 shows simulated

TABLE A-33
MODEL PARAMETERS AND COEFFICIENTS

Card Title	Parameter/Coefficient	Value	Units or Explanation
JOB	IFIRST	61	Julian day
	ILAST	274	Julian day
	NHDI	24	Hours
	IPRT	360	Hours
	ISTART	61	Julian day
	IYEAR	76	Calendar year
PHYS1	NOUTS	2	Number of Outlets
	NTRIBS	2	Number of tributaries
	NUME	8	Initial number of layers
	XLAT	48.5	Latitude, degrees
	XLONG	101.5	Longitude, degrees
	TURB	3	Turbidity factor
	AA	.2E-8	m/mb-s
	BB	.13E-8	1/mb
PHYS2	RLEN	50,000	Reservoir length, meters
	SDZMIN	.5	Minimum layer thickness, m
	SDZMAX	1.5	Maximum layer thickness, m
PHYS2+	SDZ	.8	Initial layer thickness, m
STRUCT		PORT	Specifies type of outlet
CHOICE		SPECIFIED	Outflows are specified for each port
PHYS3	ELOUT(1)	7.92	Centerline elevation of port #1, m
	AROUT(1)	100	Area of port #1, m^2
	NWELL(1)	1	Wet-well number of port #1
	FMIN(1)	0	Min. flow of port #1, m^3/s
	FMAX(1)	900	Max. flow of port #1, m^3/s
PHYS3	ELOUT(2)	1	m
	AROUT(2)	22.2	m^2
	NWELL(2)	1	Wet-well number
	FMIN(2)	0	m^3/s
	FMAX(2)	142	m^3/s
PHYS4	ACOEF(1)	11.99×10^6	Coefficients used to calculate layer volumes
	ACOEF(2)	.6989	
PHYS5	WCOEF(1)	502	Coefficients used to calculate the volume of water removed from each layer within the withdrawal zone
	WCOEF(2)	.3568	

Table A-33 (Cont)

Card Title	Parameter/Coefficient	Value	Units or Explanation
MIXING	SHELCF	.8	Sheltering coefficient
	PEFRAC	.2	Penetrative convection fraction
	CDIFW	0	Calibration parameters for computing eddy diffusion coefficients
	CDIFF	0	
	CDENS	.5	Critical density used to place inflowing water, Kg/m^3
LIGHT	EXCO	.4	Extinction coefficient, 1/m
	SURFRAC	.95	Fraction of light absorbed in a .6 m layer, dimensionless
	EXTINS	.1	Self-shading coefficient for suspended solids
SSETL	TSSETL	.2	Settling rate for suspended solids, m/day
INITO	NPOINTS	2	Number of layers for which initial conditions are specified
INIT	ELEV	0	Elevation, m
	TEMP	2	Temperature, ^oC
	DSSOL	661	Total dissolved solids, mg/l
	DTDS	0	Suspended solids, mg/l
INIT	ELEV	6.3	Elevation, m
	TEMP	0	Temperature, ^oC
	DSSOL	661	Total dissolved solids, mg/l
	DTDS	0	Suspended solids, mg/l

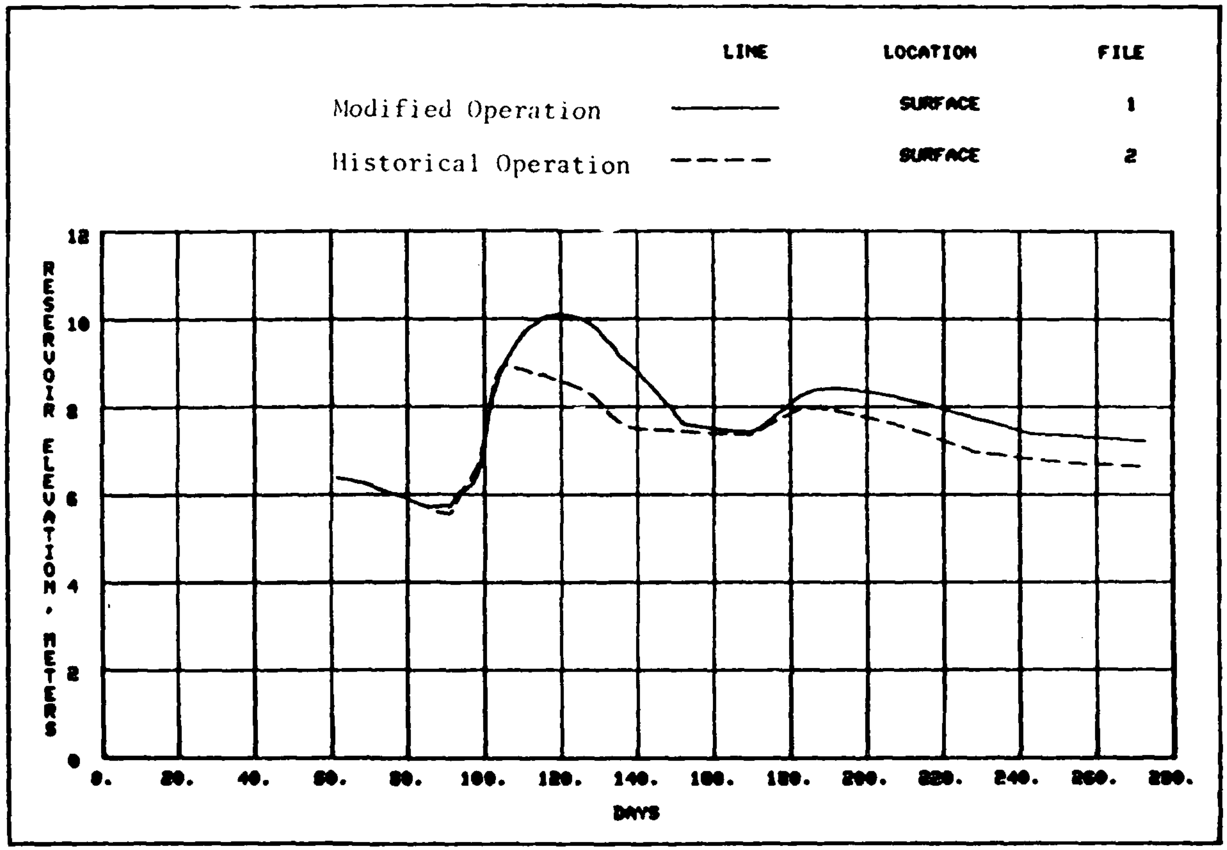

FIGURE 1

RESERVOIR OPERATION 1976 HISTORICAL AND PROPOSED MODIFICATION

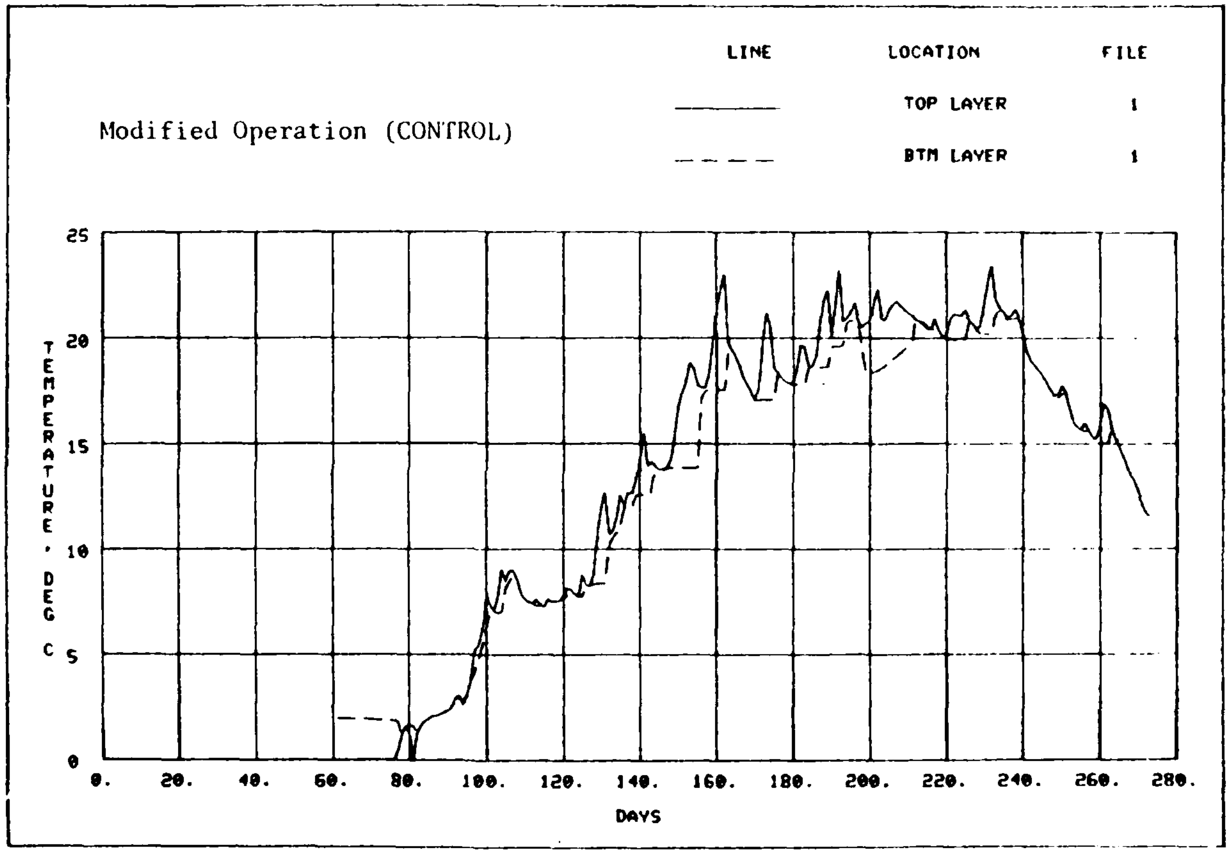

FIGURE 2

SURFACE AND BOTTOM TEMPERATURE 1976 HISTORIC OPERATION, CONTROL RUN

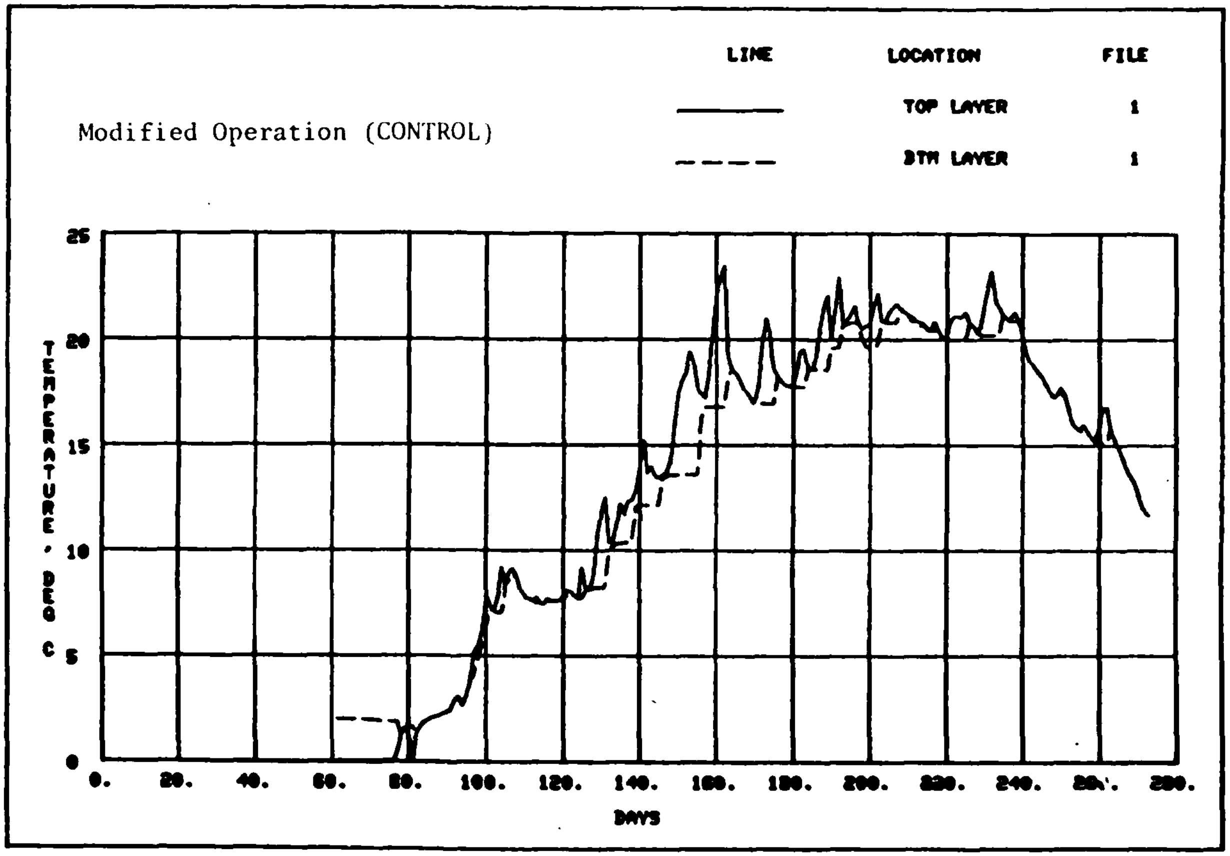

FIGURE 3

SURFACE AND BOTTOM TEMPERATURE 1976 MODIFIED OPERATION, CONTROL RUN

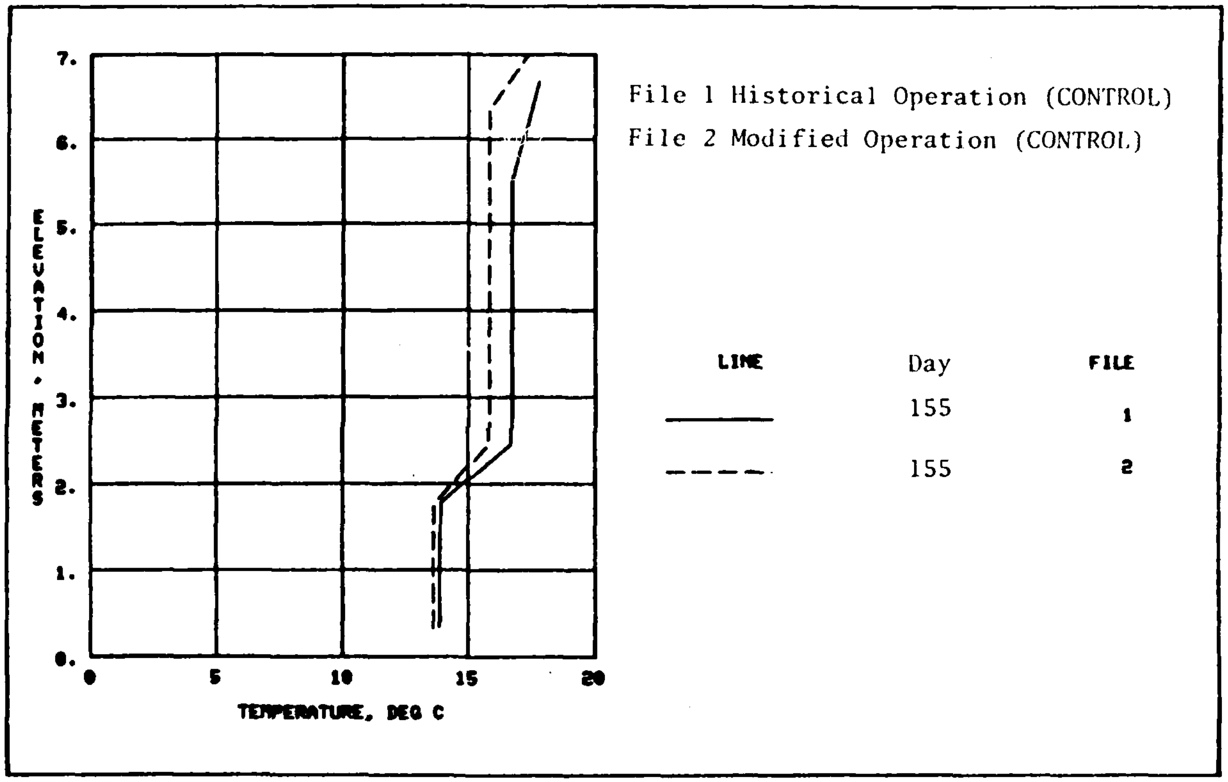

FIGURE 4

VERTICAL TEMPERATURE PROFILE DAY 155, 1976 HISTORICAL AND MODIFIED, CONTROL RUNS

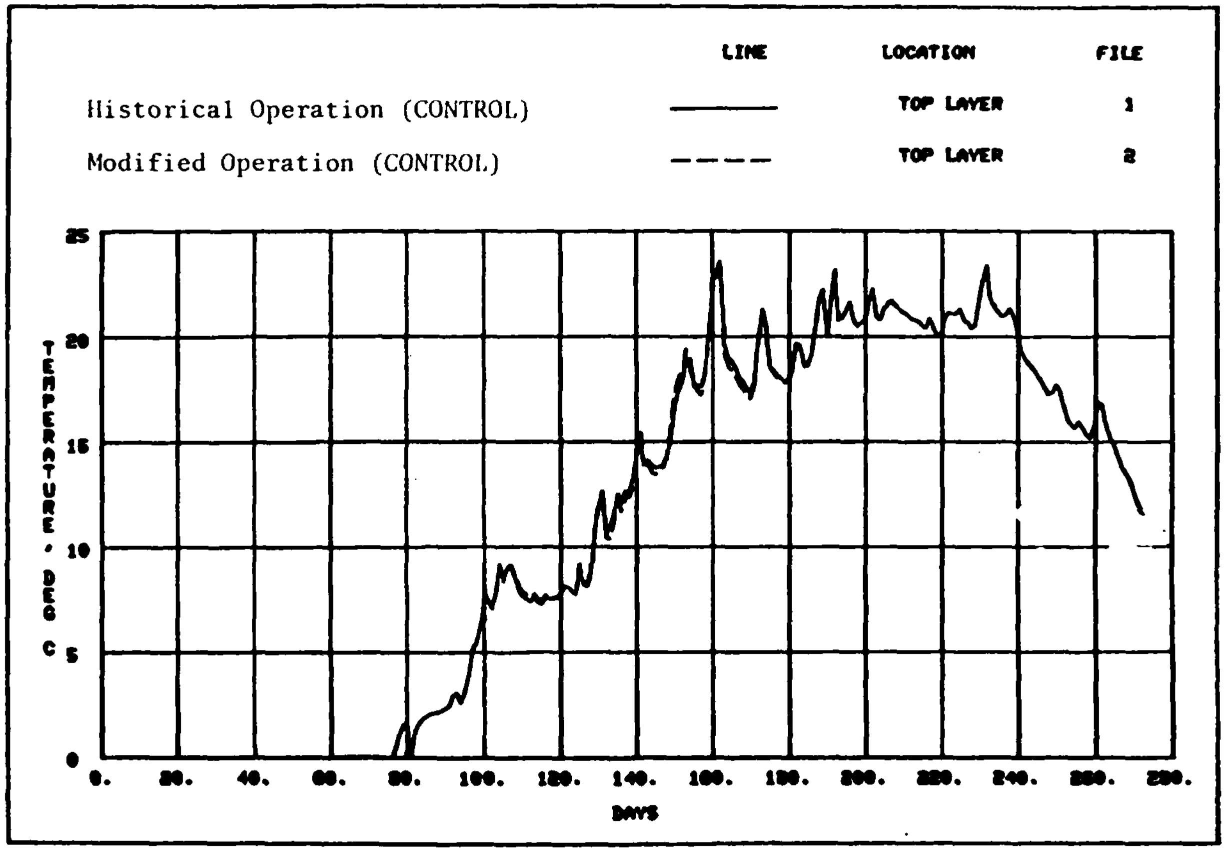

FIGURE 5

SURFACE TEMPERATURE PLOT 1976 HISTORICAL AND MODIFIED OPERATION, CONTROL RUN

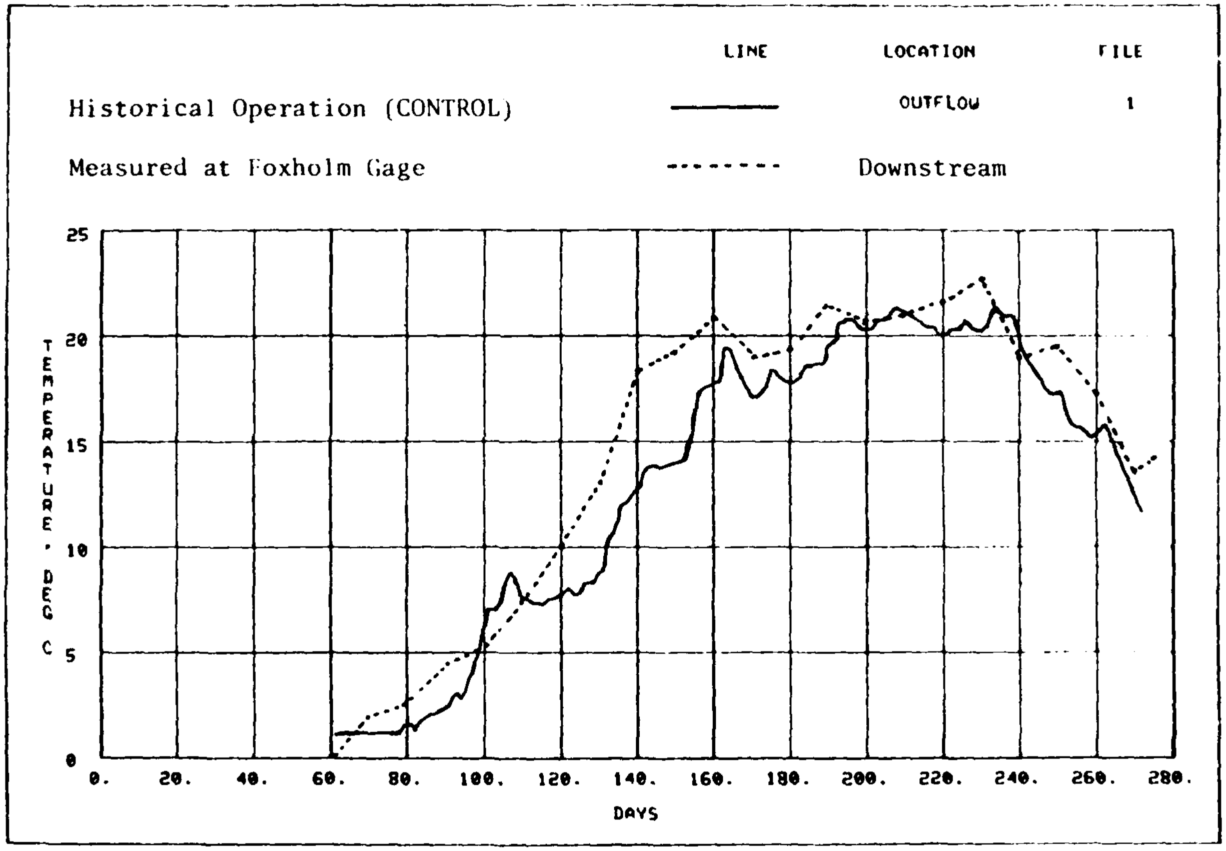

FIGURE 6

SIMULATED OUTFLOW TEMPERATURE AND MEASURED DOWNSTREAM TEMPERATURE, 1976 HISTORICAL OPERATION CONTROL RUN

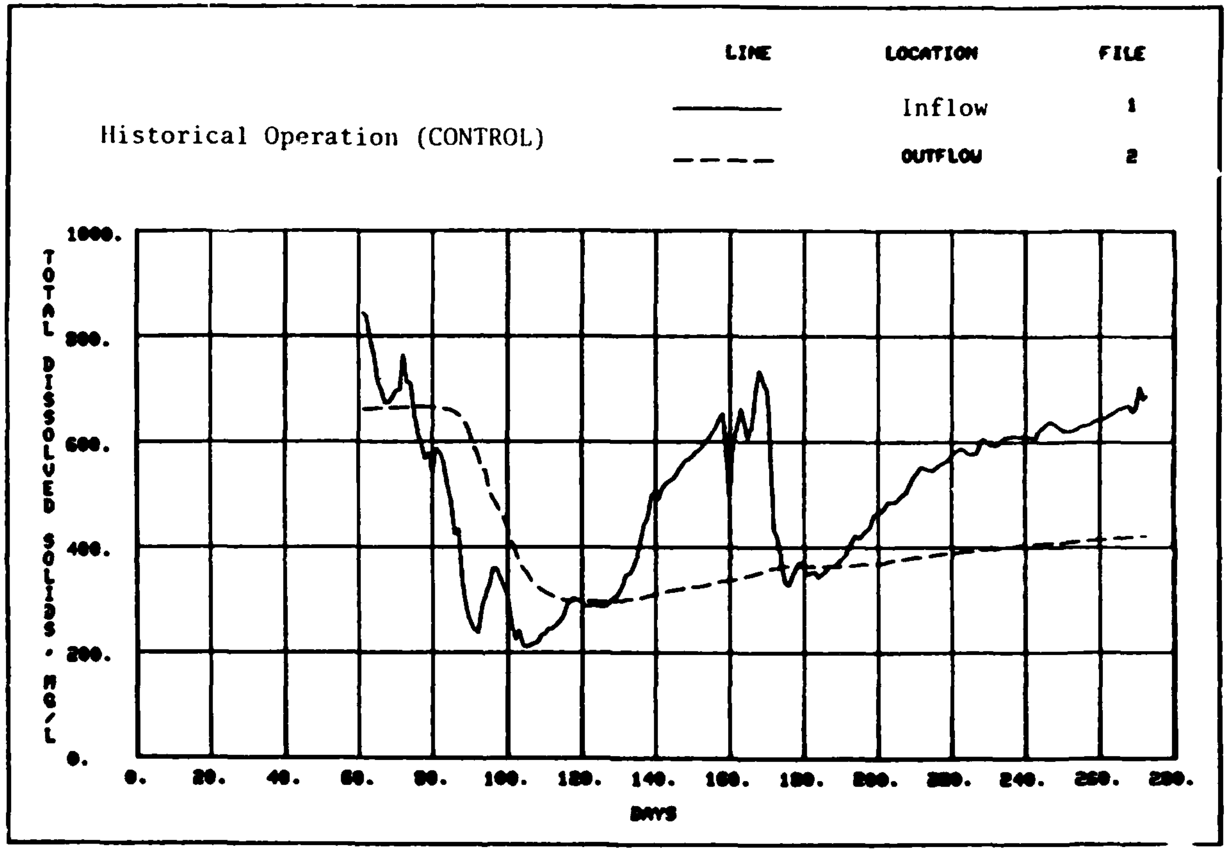

FIGURE 7

MEASURED INFLOW DISSOLVED SOLIDS AND SIMULATED OUTFLOW DISSOLVED SOLIDS
1976 HISTORICAL OPERATION, CONTROL RUN

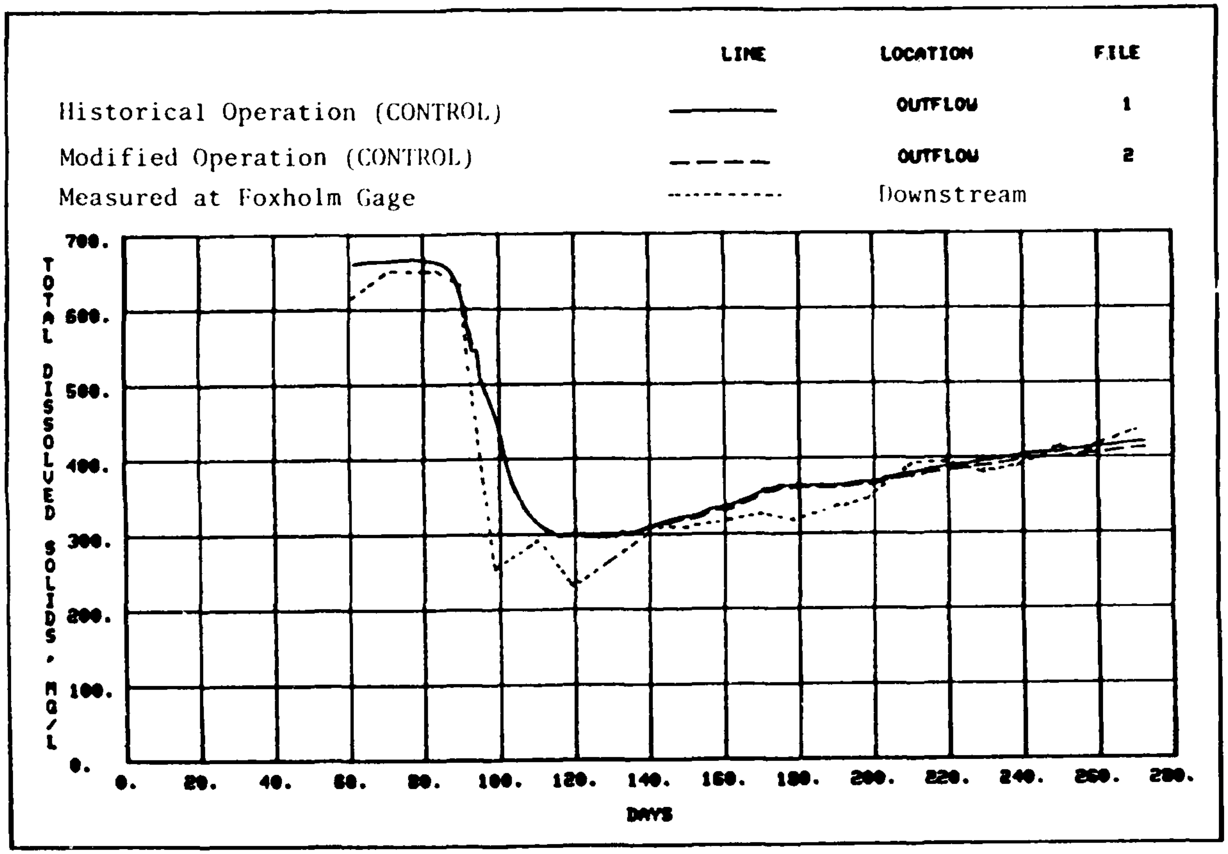

FIGURE 8

OUTFLOW DISSOLVED SOLIDS 1976 HISTORICAL AND MODIFIED OPERATION, CONTROL RUNS, AND 1976 MEASURED DISSOLVED SOLIDS AT DOWNSTREAM GAGE

outflow concentrations for both historical and the modified operation as compared to the measured concentrations at the downstream Foxholm gage. There is little difference between the concentration for the modified and historical operations and good agreement with the measured concentration at the Foxholm gage.

155. CONCLUSIONS

As anticipated, Lake Darling during 1976 was intermittently and weakly stratified during the summer months for periods of time of not more than 10 days for both the historical and the proposed flood control plan of operation. Because there is very little difference in the stratification pattern for the two operating plans, anoxic conditions in the hypolimnion, if they do develop, are not expected to be materially different between the historical and proposed operating plans. The water quality in the reservoir will be the same for either condition.

156. Further water quality studies, using the more complex CE-QUAL-R1 model, for Lake Darling are not recommended.

HYDRAULICS

HYDRAULICS

EXISTING CHANNEL CHARACTERISTICS

157. SLOPES AND STABILITY

The Souris River is a relatively sluggish stream with a very mild slope and complex meander pattern. Within the United States, its length is approximately twice that of the valley in which it flows. The average natural channel bottom slope for various reaches of the river are indicated below (see plate A-1 for referenced locations):

Upstream crossing of International boundary to Minot, North Dakota	0.47 feet/mile
Minot to Towner, North Dakota	0.76 feet/mile
Towner to downstream crossing of International boundary	0.42 feet/mile

158. The total fall of about 200 feet for the natural river length of approximately 358 miles within the United States indicates an average slope of 0.56 feet per mile.

159. The channel slope within a portion of the completed Minot Channel Project reach (Logan to Burlington) has been increased by the construction of 15 channel cutoffs. The average channel slope between the downstream and upstream limits of channel excavation (approximately 3 miles upstream of Logan to just upstream of Minot, respectively) has been increased to approximately 1.55 feet per mile. It should be noted that control structures were constructed within 12 of these cutoffs to maintain low flow water levels in the channel and direct low flows through the cutoff loops. Erosion protection measures were also utilized within the excavated channel reaches to maintain a stable channel configuration.

160. Although the Souris River has a complex meander pattern, the rate of meander development is generally quite slow within the United States. Topographic maps of the Souris River valley prepared in 1925 through 1930 were compared to more recent U.S. Geological Survey quadrangle maps and topographic maps of the valley prepared between 1970 and 1974 for the Burlington Dam project, to determine the meander progression rate of the river. These comparisons indicated that significant bank erosion has occurred only at isolated bends during the past 40 odd years. Based on field observations, project records and post-flood reports, it appears that this bank erosion has occurred primarily during the past 10 to 15 years when a number of major floods have occurred in the Souris River basin.

161. CHANNEL CAPACITIES

Existing channel capacities have been determined for contiguous reaches of the Souris River from the upstream boundary of the J. Clark Salyer National Wildlife Refuge to the downstream boundary of the Upper Souris National Wildlife Refuge (see plate A-1 for refuge boundary delineations). Previous channel capacity analyses for the Burlington Dam studies were supplemented for this report. These analyses included aerial and ground inspections between 1972 and 1982, as well as water surface profile analyses using numerical models. (These numerical models and updated water surface profiles will be discussed later in this appendix.) The approximate range of existing channel capacities for various reaches of the Souris River are indicated below.

Reach	Approximate Range of Existing Channel Capacities
J. Clark Salyer Refuge to Towner	200 to >2,000 cfs
Towner to Wintering River	600 to >2,000 cfs
Wintering River to Verendrye	1,500 to >2,000 cfs
Verendrye to Velva	1,400 to >2,000 cfs
Velva to Logan	1,400 to >2,000 cfs
Logan to Burlington(1)	2,500 to 5,000+ cfs
Burlington to Upper Souris Refuge	700 to >2,000 cfs

(1) This reach includes the completed Minot Channel Project, for which the design flow is 5,000 cfs.

162. It should be noted that there are existing emergency levees at Velva, Sawyer, Logan and the eight housing additions between Minot and Burlington which have provided emergency protection from flows much greater than the capacity of the adjacent channel. The most recent raise of these emergency levees occurred in 1976 when the peak flood flow was 9,350 cfs at Burlington and 9,820 cfs at Velva. However, portions of these emergency levees have been removed, modified, or partially eroded since 1976, such that the protection currently afforded by these levees is unknown.

WATER SURFACE PROFILES

163. GENERAL

Water surface profiles were computed for the Souris River from the J. Clark Salyer Refuge near Bantry, North Dakota, upstream to the International boundary near Sherwood, North Dakota, for conditions with and without the proposed Lake Darling project. Numerical backwater models developed

for the Burlington Dam studies and the Minot Flood Insurance Study using computer program HEC-2 (November 1976 version) were updated and expanded for this design memorandum using existing base data. These models and computed water surface profiles were used to develop the tailwater rating curve for Lake Darling Dam, support the hydraulic design of proposed levee and channel improvements and road relocations, help define real estate requirements, and to support the economic analysis of the Lake Darling project. Subsequent discussions and presentations of these water surface profiles has been separated into two major reaches downstream of the Lake Darling Dam and one upstream of the dam because of the differing data bases, required computational methodology and uses of this information. It is assumed for this discussion that the reader has a general understanding of the proposed project features and associated locations from information presented in the main portion of this design memorandum.

164. J. CLARK SALYER REFUGE

Approximate water surface profiles through the J. Clark Salyer Refuge for discharges of 600 cfs and 800 cfs were previously developed during Burlington Dam studies to evaluate the operational capability of the refuge dams during low-flow reservoir evacuation periods. These discharges represented 500 cfs and 700 cfs long-term releases from Burlington Dam plus 100 cfs local inflow between the dam and Salyer Refuge. The associated water surface profiles are shown on Plate 20. These profiles were computed using slope-area methods and Manning's equation. The slope used was 0.00008 (0.42 feet per mile) and the channel roughness coefficient (Manning's "n") used was 0.048, based on previous evaluations of the reach from Towner downstream. The overbank roughness coefficient was estimated to be 0.100. Cross section data were taken from existing (prior to construction) ground profiles shown on construction drawings for the J. Clark Salyer structures. The water surface elevations downstream of Dam 357 were obtained from a U.S. Geological Survey rating curve for the gage near Westhope, North Dakota.

165. BANTRY TO LAKE DARLING DAM

Detailed numerical backwater models were developed during Burlington Dam studies for the reach from the upstream boundary of the Salyer Refuge, near Bantry to the proposed Burlington Dam Site, approximately 2 miles upstream of Burlington. The models from Logan to Burlington were subsequently updated in 1980-81 for use in the Minot Flood Insurance Study. These models reflect completed Minot Channel Project conditions. The models in the Velva area were revised and updated in 1982 for use in design of proposed flood control measures at Velva, as part of the Lake Darling project. Detailed discussions of these models are presented in Design Memorandum No. 4, Velva Improvements, dated November 1982.

166. The base data used to develop the backwater models between Bantry and Burlington included approximately 200 channel and structure cross sections surveyed in 1975 and 1976, and floodplain topography developed from aerial

photographs taken between 1970 and 1974. The floodplain topography, which has a contour interval of 4 feet and a scale of 1" = 400', was used to extend the channel cross sections and determine reach lengths. Design plans and as-built channel cross sections were also utilized throughout the Minot Channel Project reach.

167. Calibration of the models between Bantry and Burlington was primarily accomplished using high water profiles from the 1976 and 1979 floods. The peak discharges for these floods were obtained from U.S. Geological Survey gage data, Corps of Engineers discharge measurements and post-flood report analyses. The peak discharges on the Souris River for the 1976 flood varied from 8,600 cfs above the confluence with the Des Lacs River at Burlington, to 9,900 cfs at Verendrye and 9,330 cfs at Bantry. The 1979 flood data were used only within the Logan to Burlington reach, where a high water profile and associated discharge measurements of approximately 5,750 cfs were obtained near the peak of the flood. The calibrated models generally reproduced the historic flood profiles to within ±0.5 foot or less. The Manning's "n" values used in these models ranged from 0.035 to 0.054 for the channel (0.035 was used for the excavated channel through Minot) and 0.06 to 0.14 for the overbanks. Contraction and expansion loss coefficients ranged from 0.1 to 0.3 in relatively uniform reaches to 0.5 and 0.7 at abrupt transitions.

168. An HEC-2 model was developed between the proposed Burlington Dam site and the Lake Darling Dam for this study. The base data for this model included about 60 channel cross sections surveyed in 1975 between Burlington and the downstream boundary of the Upper Souris Refuge; floodplain topography with a contour interval of 5 feet which was developed from aerial photographs taken in 1973; seven channel cross sections surveyed in 1960 within portions of the refuge; surveys of refuge Dams 96 and 87 obtained in 1978; county highway department drawings of the bridges within the reach; and ten cross sections of the levees around refuge Ponds A, B and C obtained in 1978. Ground elevation data were not available within the backwater areas of Dams 87 and 96. Estimates of ground elevations in these areas and along the road crossings were based on the available topographic maps.

169. The numerical model between Burlington and Lake Darling was calibrated to the limited number of high water elevations available for the 1976 flood in this reach. The calibrated channel roughness coefficients varied from 0.035 in the backwater areas of Dams 87 and 96, to 0.040 for the remainder of the reach. Overbank roughness coefficients varied from 0.05 to 0.075. These coefficients are somewhat lower than for similar reaches downstream of Burlington. It appears that this situation may be related to the limited degree of accuracy of the available topographic maps (5 foot contour interval).

170. Water surface profiles were computed from Bantry to Lake Darling for existing (without-project) and proposed (i.e., modified or with-project) conditions for the 50-, 20-, 10-, 4-, 2-, 1-, and 0.2-percent chance flood events

(i.e., the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year floods, respectively). These computed water surface profiles are shown on plates A-47 through A-72 . The corresponding computed water surface elevations are tabulated in table A-34 . The 50-percent chance flood profile is essentially the same for with and without project conditions, because the computed peak discharges are the same and because the proposed local protection measures downstream of Lake Darling would have only minor effects on floods of this magnitude. (The hydraulic design of these proposed local protection measures will be discussed later in this appendix.) The 0.2-percent chance flood profile was computed only for proposed project conditions because the peak discharges for this flood frequency are essentially the same with the proposed Lake Darling Dam raise as without the raise, and because the proposed local protection measures downstream of Lake Darling were designed for much smaller floods and were, therefore, assumed to have failed for this large flood event.

171. The existing or without-project conditions computed water surface profiles reflect the completed Minot Channel Project but do not reflect the presence of emergency levees. The with-project conditions computed water surface profiles reflect the presence of the proposed levee and channel modifications at Velva, Sawyer, and the eight housing additions between Minot and Burlington. For this analysis, the proposed levees were assumed to be effective up to the with-project conditions 1-percent chance flood discharges. A Manning's "n" value of 0.035 was utilized for the proposed trapezoidal channel reaches. Elsewhere, the calibrated channel and overbank roughness coefficients were utilized for all water surface profile computations up to and including the 0.2-percent chance flood. Starting water surface elevations at Bantry were obtained from a rating curve for the U.S. Geological Survey gage at that location, as shown on plate 45R of Supplement No. 1 to Design Memorandum No. 1, Burlington Dam, Souris River, N.D.

172. LAKE DARLING DAM TO SHERWOOD

Numerical HEC-2 models for water surface profile computation from Lake Darling Dam upstream to the International boundary near Sherwood were developed for this study using existing data. An approximate HEC-2 model was developed for the Burlington Dam studies from the upstream boundary of the Upper Souris Refuge to the border near Sherwood in order to analyze backwater effects for various pool levels behind Burlington Dam. This numerical model was based on topographic mapping of the valley, which was developed from aerial photographs taken in 1973, and which has a scale of 1" = 400' and contour interval of 5 feet. The channel cross sections were estimated for this model, as were the hydraulic losses at bridge crossings. This numerical model was updated and extended downstream to Lake Darling Dam for this study. Construction drawings obtained from the state and county highway departments and the Soo Line Railroad were used to define existing bridge geometry and adjacent road profiles. The channel cross sections at the bridges were used to estimate a thalweg profile and channel geometry for the reaches between road crossings, in conjunction with the previously mentioned topographic mapping. Bottom elevations within the Lake Darling conservation pool were obtained from topographic mapping of the valley prepared between 1925 and 1930 (prior to

TABLE A-34

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL WITH & WITHOUT	5-YR CWSEL WITHOUT PROJECT	5-YR CWSEL WITH PROJECT	10-YR CWSEL WITHOUT PROJECT	10-YR CWSEL WITH PROJECT	25-YR CWSEL WITHOUT PROJECT	25-YR CWSEL WITH PROJECT	50-YR CWSEL WITHOUT PROJECT	50-YR CWSEL WITH PROJECT	100-YR CWSEL WITHOUT PROJECT	100-YR CWSEL WITH PROJECT	500-YR CWSEL WITH PROJECT
BANTRY		Q=1050CFS	Q=2200	2100	Q=3750	3350	Q=7150	5600	Q=11100	8700	Q=17000	14400	41800
	149	1438.4	1440.3	1440.2	1441.0	1440.9	1441.8	1441.5	1442.4	1442.1	1443.3	1442.9	1445.0
	148	1438.7	1440.7	1440.6	1441.6	1441.5	1442.7	1442.3	1443.5	1443.1	1444.3	1444.0	1446.3
	147	1438.9	1440.9	1440.8	1441.8	1441.6	1442.9	1442.5	1443.7	1443.2	1444.5	1444.2	1446.6
	146	1440.0	1441.6	1441.5	1442.4	1442.2	1443.5	1443.1	1444.4	1443.9	1445.3	1444.9	1447.7
	145	1440.4	1441.8	1441.7	1442.6	1442.4	1443.7	1443.3	1444.6	1444.1	1445.6	1445.2	1448.0
	144.90	1441.3	1442.5	1442.5	1443.3	1443.1	1444.4	1444.0	1445.2	1444.8	1446.2	1445.8	1448.7
BR SEC 25	144.10	1441.3	1442.6	1442.5	1443.4	1443.2	1444.4	1444.0	1445.3	1444.8	1446.2	1445.8	1448.7
T158N R76W	144.50	1441.4	1442.6	1442.6	1443.4	1443.2	1444.5	1444.0	1445.3	1444.8	1446.2	1445.8	1448.7
	144	1443.3	1445.0	1444.9	1445.5	1445.4	1446.3	1446.0	1446.9	1446.5	1447.7	1447.4	1450.0
	143	1444.0	1445.4	1445.4	1446.0	1445.9	1446.8	1446.5	1447.5	1447.1	1448.3	1448.0	1450.7
	142	1446.2	1446.5	1446.5	1447.1	1447.0	1448.0	1447.6	1448.7	1448.3	1449.5	1449.2	1452.0
	141	1446.8	1447.3	1447.3	1447.8	1447.6	1448.5	1448.2	1449.2	1448.8	1450.0	1449.7	1452.5
	140	1448.2	1448.7	1448.6	1449.1	1449.0	1449.8	1449.5	1450.4	1450.0	1451.2	1450.9	1453.6
	139	1450.1	1450.6	1450.6	1451.0	1450.9	1451.7	1451.4	1452.3	1452.0	1453.1	1452.8	1455.4
	138	1450.9	1452.0	1452.0	1452.6	1452.5	1453.3	1453.0	1453.9	1453.6	1454.7	1454.4	1456.9
	137	1451.2	1452.5	1452.4	1453.1	1452.9	1453.9	1453.6	1454.6	1454.2	1455.4	1455.1	1457.8
RED CROSS SCH #1		Q=1150CFS	Q=2300	2200	Q=3850	3400	Q=7250	5700	Q=11200	8800	Q=17100	14500	42400
	136	1451.3	1452.7	1452.6	1453.3	1453.2	1454.3	1453.9	1455.1	1454.7	1456.0	1455.7	1458.4
	135	1451.5	1453.1	1453.0	1453.9	1453.7	1455.1	1454.7	1456.0	1455.5	1457.0	1456.6	1459.4
	134.10	1451.5	1453.2	1453.1	1454.1	1453.8	1455.3	1454.8	1456.2	1455.7	1457.1	1456.7	1459.6
BR SEC 19	134	1451.5	1453.2	1453.1	1454.1	1453.8	1455.3	1454.8	1456.3	1455.7	1457.1	1456.8	1464.3
T157N R75W	133.90	1451.5	1453.2	1453.1	1454.1	1453.9	1455.6	1455.0	1456.8	1456.1	1458.2	1457.6	1464.3
	133.50	1451.6	1453.3	1453.2	1454.3	1454.0	1455.8	1455.2	1456.9	1456.3	1458.4	1457.8	1464.4
	133.10	1451.7	1453.4	1453.2	1454.3	1454.1	1455.8	1455.2	1457.0	1456.3	1458.4	1457.8	1464.4
	133.05	1451.7	1453.4	1453.3	1454.3	1454.1	1455.8	1455.2	1457.0	1456.3	1458.4	1457.8	1464.4
BR SEC 31	133	1451.7	1453.4	1453.3	1454.6	1454.1	1455.9	1455.3	1457.1	1456.4	1458.6	1458.0	1464.7
T157N R75W	132	1451.8	1453.5	1453.4	1454.6	1454.2	1455.9	1455.3	1457.1	1456.4	1458.6	1458.0	1464.7
TOWNER		Q=1200CFS	Q=2300	2200	Q=3850	3400	Q=7250	5700	Q=11200	8800	Q=17100	14500	42400
	131	1452.9	1453.8	1453.7	1454.8	1454.5	1456.1	1455.6	1457.3	1456.6	1458.8	1458.2	1464.8
	130	1453.4	1454.4	1454.3	1455.2	1454.9	1456.4	1455.9	1457.5	1456.9	1458.9	1458.3	1464.8
	129	1453.5	1454.4	1454.3	1455.2	1455.0	1456.4	1455.9	1457.6	1456.9	1459.0	1458.4	1464.9
HWY 14 BR	128.10	1453.5	1454.4	1454.3	1455.2	1454.9	1456.3	1455.8	1457.3	1456.7	1458.5	1458.0	1464.9
AT TOWNER	128	1453.5	1454.4	1454.3	1455.2	1454.9	1456.3	1455.8	1457.3	1456.7	1458.4	1458.0	1468.4
	127	1453.5	1454.5	1454.4	1455.4	1455.1	1456.8	1456.2	1458.1	1457.3	1459.7	1459.0	1468.4
	126.10	1453.5	1454.6	1454.4	1455.5	1455.2	1456.8	1456.3	1458.0	1457.3	1459.5	1458.9	1468.4
	126	1453.5	1454.6	1454.4	1455.5	1455.2	1456.9	1456.3	1458.1	1457.3	1459.6	1459.0	1470.8
	125.90	1453.5	1454.6	1454.4	1455.5	1455.2	1457.0	1456.4	1458.2	1457.4	1459.9	1459.2	1470.8
	125	1453.6	1454.9	1454.7	1456.1	1455.6	1457.1	1456.5	1458.3	1457.5	1460.0	1459.3	1470.8
	124	1453.8	1455.2	1455.0	1456.4	1455.9	1457.2	1456.7	1458.4	1457.7	1460.1	1459.4	1470.8
B.N. RR BR	123.10	1453.8	1455.3	1455.1	1456.4	1456.0	1457.2	1456.7	1458.2	1457.6	1459.7	1459.1	1470.8
AT TOWNER	123	1453.8	1455.3	1455.1	1456.4	1456.0	1457.2	1456.7	1458.3	1457.6	1460.5	1459.2	1470.9

TABLE A-34 (continued, page 2 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL	5-YR CWSEL		10-YR CWSEL		25-YR CWSEL		50-YR CWSEL		100-YR CWSEL		500-YR CWSEL
		WITH & WITHOUT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITH PROJECT
	122.90	1453.8	1455.4	1455.2	1456.6	1456.1	1457.6	1457.0	1459.1	1458.2	1461.5	1460.2	1470.9
	122.20	1454.2	1455.7	1455.5	1456.7	1456.3	1457.8	1457.2	1459.2	1458.3	1461.5	1460.3	1470.9
B.N. RR BR	122.10	1454.3	1455.7	1455.5	1456.7	1456.3	1457.8	1457.3	1459.2	1458.4	1461.5	1460.3	1470.9
U/S OF TOWNER	122	1454.3	1455.7	1455.5	1457.1	1456.6	1457.8	1457.3	1459.3	1458.4	1461.6	1460.4	1470.9
	122.50	1454.3	1455.8	1455.6	1457.2	1456.7	1457.9	1457.3	1459.3	1458.4	1461.6	1460.4	1470.9
	121	1454.5	1455.9	1455.7	1457.2	1456.7	1457.9	1457.4	1459.3	1458.5	1461.6	1460.4	1470.9
	120	1454.6	1455.9	1455.8	1457.2	1456.8	1458.0	1457.4	1459.4	1458.5	1461.6	1460.4	1470.9
	119	1455.0	1456.2	1456.1	1457.4	1457.0	1458.1	1457.6	1459.4	1458.6	1461.7	1460.5	1471.0
	118.10	1455.0	1456.2	1456.1	1457.5	1457.0	1458.1	1457.5	1459.5	1458.6	1461.7	1460.5	1471.0
US HWY 82 BR	118	1455.0	1456.2	1456.1	1457.5	1457.1	1458.4	1457.7	1459.8	1459.0	1461.4	1460.2	1471.0
	117.10	1455.0	1456.3	1456.1	1457.6	1457.1	1458.7	1457.9	1460.5	1459.6	1461.9	1461.1	1471.0
	117	1455.5	1457.4	1457.1	1459.1	1458.8	1460.1	1459.8	1460.8	1460.2	1462.1	1461.3	1471.0
	116	1456.0	1458.5	1458.2	1459.7	1459.7	1460.4	1460.2	1461.1	1460.6	1462.2	1461.6	1471.0
BR SEC 29	115.10	1456.0	1458.5	1458.2	1459.7	1459.7	1460.4	1460.2	1461.1	1460.7	1462.2	1461.6	1471.0
T156N R76W	115	1456.0	1458.6	1458.3	1459.6	1459.6	1460.4	1460.2	1461.1	1460.7	1462.3	1461.6	1471.1
	114.90	1456.1	1458.6	1458.3	1459.8	1459.8	1460.5	1460.3	1461.1	1460.7	1462.3	1461.6	1471.1
	114	1456.2	1458.7	1458.8	1459.9	1460.0	1460.6	1460.6	1461.2	1461.0	1462.4	1461.9	1471.1
	113	1456.3	1458.8	1459.4	1459.9	1460.4	1460.6	1461.0	1461.3	1461.5	1462.4	1462.3	1471.1
	112	1456.5	1458.8	1459.7	1459.9	1460.7	1460.8	1461.3	1461.5	1461.9	1462.6	1462.7	1471.2
	111	1456.7	1459.3	1460.0	1460.7	1461.1	1462.3	1462.1	1463.3	1462.9	1464.2	1463.9	1471.3
EATON DAM		Q=1250CFS	Q=2500	2400	Q=4050	3500	Q=7450	5900	Q=11400	8900	Q=17300	14700	43300
	109	1458.4	1462.5	1460.0	1463.5	1461.1	1464.4	1462.1	1464.9	1462.9	1465.8	1463.9	1473.3
	108	1458.6	1462.5	1460.3	1463.5	1461.4	1464.5	1462.4	1465.1	1463.3	1466.0	1464.4	1473.4
	107	1458.7	1462.7	1460.6	1463.8	1461.9	1464.8	1463.4	1465.5	1464.4	1466.4	1465.4	1473.4
	106	1458.9	1462.9	1461.0	1464.1	1462.4	1465.1	1464.1	1465.9	1465.1	1466.8	1466.0	1473.5
	105	1459.0	1463.1	1461.3	1464.3	1462.9	1465.3	1464.5	1466.1	1465.3	1467.0	1466.3	1473.5
	104.40	1459.1	1463.3	1461.5	1464.3	1463.2	1465.4	1464.6	1466.1	1465.4	1467.0	1466.4	1473.6
NELSEN'S BR	104.50	1459.1	1463.3	1461.5	1464.3	1463.2	1465.4	1464.6	1466.1	1465.4	1467.1	1466.4	1473.6
	104.60	1459.2	1463.3	1461.6	1464.3	1463.2	1465.4	1464.6	1466.1	1465.4	1467.1	1466.4	1473.6
	104	1459.6	1463.9	1462.5	1464.6	1464.1	1465.6	1465.0	1466.4	1465.7	1467.3	1466.7	1473.7
	103	1459.8	1464.0	1462.8	1464.7	1464.3	1465.7	1465.1	1466.5	1465.8	1467.4	1466.8	1473.7
	102.60	1459.9	1464.1	1463.0	1464.8	1464.5	1465.8	1465.3	1466.6	1466.0	1467.6	1467.0	1473.7
	102.50	1459.9	1464.1	1463.0	1464.9	1464.5	1465.8	1465.3	1466.6	1466.0	1467.6	1467.0	1473.7
CLWRT SEC 24	102.40	1459.9	1464.1	1463.0	1464.8	1464.5	1465.8	1465.3	1466.6	1466.0	1467.6	1467.0	1473.7
T155N R77W	102.30	1459.9	1464.1	1463.0	1464.8	1464.5	1465.8	1465.3	1466.6	1466.0	1467.6	1467.0	1473.7
	102.20	1460.0	1464.2	1463.1	1464.9	1464.5	1465.8	1465.3	1466.6	1466.0	1467.5	1467.0	1473.7
	102	1460.0	1464.2	1463.1	1464.9	1464.5	1465.9	1465.3	1466.6	1466.0	1467.6	1467.0	1473.7
	101	1460.3	1464.5	1463.6	1465.2	1464.9	1466.1	1465.6	1466.8	1466.3	1467.8	1467.3	1473.8
	100	1460.4	1464.7	1463.9	1465.4	1465.1	1466.3	1465.9	1467.0	1466.5	1467.9	1467.4	1473.8
	99	1460.6	1465.0	1464.2	1465.7	1465.4	1466.6	1466.2	1467.3	1466.8	1468.1	1467.7	1473.8
	98	1460.7	1465.0	1464.3	1465.8	1465.5	1466.6	1466.3	1467.3	1466.9	1468.2	1467.7	1473.8
BR SEC 23-26	97.10	1460.8	1465.1	1464.5	1465.9	1465.7	1466.7	1466.4	1467.3	1466.8	1468.1	1467.7	1473.8
T155N R77W	97	1460.8	1465.2	1464.5	1466.1	1465.8	1467.2	1466.8	1467.9	1467.6	1468.8	1468.4	1473.8
	96	1461.1	1465.4	1464.8	1466.3	1466.0	1467.5	1467.0	1468.2	1467.9	1469.1	1468.7	1473.9
	95	1461.3	1465.6	1465.1	1466.8	1466.4	1468.2	1467.7	1469.0	1468.5	1469.8	1469.5	1474.1

TABLE A-34 (continued, page 3 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL	5-YR CWSEL		10-YR CWSEL		25-YR CWSEL		50-YR CWSEL		100-YR CWSEL		500-YR CWSEL
		WITH & WITHOUT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITH PROJECT
	94	1461.8	1466.5	1466.0	1468.3	1467.8	1470.0	1469.4	1471.0	1470.4	1472.1	1471.6	1475.3
	93	1462.3	1467.2	1466.7	1469.4	1468.7	1471.1	1470.5	1472.1	1471.5	1473.3	1472.8	1476.6
	92	1462.9	1467.9	1467.4	1470.3	1469.6	1472.0	1471.4	1473.1	1472.5	1474.3	1473.8	1477.7
WINTERING RIVER		Q=1300CFS	Q=2550	2420	Q=4100	3500	Q=7500	5900	Q=11500	8900	Q=17400	14700	43500
	91	1463.6	1468.6	1468.1	1471.1	1470.4	1472.8	1472.2	1473.9	1473.3	1475.1	1474.6	1478.6
BR SEC 32-33	90.10	1463.6	1468.6	1468.1	1471.1	1470.5	1472.8	1472.2	1473.9	1473.3	1475.1	1474.7	1478.7
T155N R77W	90	1463.6	1468.6	1468.1	1471.1	1470.5	1473.1	1472.2	1473.5	1473.6	1474.0	1473.8	1478.7
	89.10	1463.6	1468.6	1468.1	1471.2	1470.5	1473.3	1472.4	1474.2	1474.0	1475.6	1475.0	1478.8
	89	1464.4	1469.5	1469.0	1472.1	1471.4	1474.2	1473.3	1475.2	1474.8	1476.6	1476.0	1480.0
	88	1465.0	1470.2	1469.7	1472.7	1472.1	1474.6	1473.8	1475.7	1475.2	1477.1	1476.5	1480.6
	87	1466.0	1471.2	1470.7	1473.6	1473.0	1475.3	1474.6	1476.5	1475.9	1477.9	1477.3	1481.7
	86	1467.1	1472.2	1471.8	1474.5	1473.9	1476.1	1475.4	1477.2	1476.6	1478.6	1478.0	1482.6
	85	1468.1	1473.0	1472.6	1475.1	1474.6	1476.6	1476.0	1477.8	1477.1	1479.2	1478.6	1483.3
	84	1468.9	1473.7	1473.3	1475.6	1475.1	1477.1	1476.5	1478.3	1477.6	1479.6	1479.0	1483.7
	83	1469.4	1474.2	1473.8	1475.9	1475.4	1477.3	1476.7	1478.5	1477.8	1479.9	1479.3	1484.0
	82	1469.8	1474.5	1474.1	1476.0	1475.6	1477.4	1476.8	1478.6	1477.9	1480.0	1479.4	1484.1
	81	1470.4	1474.9	1474.6	1476.1	1475.7	1477.6	1477.0	1478.8	1478.0	1480.1	1479.5	1484.3
	80	1471.1	1475.2	1475.0	1476.3	1475.9	1477.8	1477.2	1478.9	1478.2	1480.4	1479.8	1484.6
BR SEC 10-11	79.10	1471.7	1475.7	1475.6	1476.8	1476.4	1478.1	1477.6	1479.3	1478.6	1480.6	1480.0	1484.8
T154N R78W	79	1471.7	1475.7	1475.6	1476.8	1476.4	1478.1	1477.6	1479.2	1478.6	1480.7	1480.0	1484.9
	79.50	1471.7	1475.8	1475.6	1476.8	1476.5	1478.4	1477.8	1479.3	1478.8	1480.7	1480.1	1484.9
	78	1472.5	1476.8	1476.6	1478.4	1477.9	1480.0	1479.4	1480.9	1480.4	1482.1	1481.6	1486.0
	77	1473.4	1477.8	1477.5	1479.4	1479.0	1481.0	1480.4	1482.0	1481.4	1483.3	1482.7	1487.1
	76	1474.0	1478.4	1478.2	1480.0	1479.5	1481.4	1480.9	1482.6	1481.9	1483.8	1483.3	1487.8
	75	1475.4	1479.8	1479.6	1480.9	1480.6	1482.3	1481.7	1483.4	1482.7	1484.8	1484.2	1488.9
	74	1475.9	1480.1	1480.0	1481.2	1480.8	1482.5	1482.0	1483.6	1482.9	1485.0	1484.4	1489.1
USGS GAGE	73.50	1476.2	1480.4	1480.2	1481.4	1481.1	1482.7	1482.1	1483.8	1483.1	1485.2	1484.6	1489.3
VERENDRYE		Q=1330CFS	Q=2600	2470	Q=4150	3550	Q=7500	5900	Q=11600	9000	Q=17500	14800	43700
	73	1476.5	1480.7	1480.5	1481.7	1481.4	1483.0	1482.5	1484.0	1483.3	1485.3	1484.8	1489.4
	72	1477.1	1481.3	1481.1	1482.4	1482.1	1483.7	1483.2	1484.7	1484.1	1485.9	1485.4	1489.8
	71	1477.9	1482.4	1482.2	1483.9	1483.4	1485.1	1484.6	1486.0	1485.4	1487.0	1486.5	1490.6
	70	1478.4	1482.9	1482.7	1484.3	1483.9	1485.5	1485.0	1486.3	1485.8	1487.3	1486.9	1490.8
BR SEC 20-29	69.10	1478.4	1482.9	1482.7	1484.3	1483.9	1485.5	1485.0	1486.3	1485.8	1487.3	1486.9	1490.8
T154N R78W	69	1478.4	1482.9	1482.7	1484.3	1483.9	1485.5	1485.0	1486.3	1485.8	1487.3	1486.9	1490.8
	68.90	1478.4	1483.0	1482.8	1484.5	1484.1	1485.6	1485.2	1486.4	1485.9	1487.4	1487.0	1490.8
	68	1479.1	1483.5	1483.3	1484.9	1484.5	1486.0	1485.5	1486.8	1486.3	1487.7	1487.3	1491.0
	67	1479.8	1484.3	1484.0	1485.6	1485.2	1486.7	1486.3	1487.5	1487.0	1488.4	1488.0	1491.6
	66.10	1480.8	1484.9	1484.7	1486.4	1486.0	1487.9	1487.3	1488.8	1488.3	1489.6	1489.3	1493.1
FAS 294 BR	66	1480.8	1484.9	1484.7	1486.5	1486.0	1487.9	1487.3	1488.9	1488.3	1491.3	1489.6	1493.6
	65.90	1480.9	1485.1	1484.8	1486.7	1486.2	1488.6	1487.8	1490.6	1489.3	1493.4	1492.1	1494.7
	65	1481.2	1485.4	1485.2	1487.3	1486.7	1489.6	1488.6	1491.5	1490.4	1493.7	1492.6	1495.2
B.N. RR BR	64.10	1481.2	1485.4	1485.2	1487.3	1486.7	1489.6	1488.6	1491.6	1490.4	1493.8	1492.7	1495.6
AT VERENDRYE	64	1481.2	1485.4	1485.2	1487.3	1486.7	1489.6	1488.6	1491.6	1490.4	1493.8	1492.7	1496.0

TABLE A-34 (continued, page 4 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL	5-YR CWSEL		10-YR CWSEL		25-YR CWSEL		50-YR CWSEL		100-YR CWSEL		500-YR CWSEL
		WITH & WITHOUT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITH PROJECT
	63.90	1481.2	1485.5	1485.2	1487.3	1486.8	1489.8	1488.7	1491.8	1490.6	1494.0	1492.9	1497.3
	63	1481.3	1485.7	1485.4	1487.7	1487.0	1490.3	1489.1	1492.5	1491.2	1495.0	1493.9	1500.3
	62	1481.7	1486.2	1485.9	1488.4	1487.7	1491.2	1490.0	1493.3	1492.0	1495.7	1494.6	1501.0
	61	1482.3	1486.9	1486.6	1489.6	1488.7	1492.7	1491.6	1494.7	1493.6	1496.8	1495.8	1502.0
	60	1483.2	1488.2	1487.8	1491.3	1490.3	1494.1	1493.1	1495.8	1494.8	1497.7	1496.8	1503.0
	59	1483.6	1488.7	1488.3	1491.9	1490.9	1494.6	1493.7	1496.2	1495.3	1498.1	1497.3	1503.4
BR SEC 34	56.10	1483.6	1488.7	1488.3	1491.9	1490.9	1494.5	1493.6	1496.1	1495.1	1498.1	1497.2	1503.4
T154N R79W	56	1483.6	1488.7	1488.4	1491.9	1490.9	1494.7	1493.6	1496.0	1495.0	1498.1	1497.2	1503.5
	55.90	1483.7	1488.7	1488.4	1492.0	1490.9	1494.8	1493.9	1496.3	1495.5	1498.2	1497.4	1503.6
	55	1484.7	1489.6	1489.4	1492.9	1491.9	1495.8	1494.2	1497.2	1495.8	1498.7	1497.6	1503.8
	54	1486.5	1491.4	1491.2	1494.1	1493.1	1496.5	1495.4	1497.7	1496.7	1499.1	1498.2	1504.1
	53	1488.1	1492.9	1492.6	1494.7	1493.9	1497.1	1496.0	1498.4	1497.4	1499.8	1499.1	1504.8
	52	1490.0	1494.6	1494.3	1495.8	1495.2	1497.8	1496.9	1499.2	1498.2	1500.7	1499.9	1505.6
	51	1491.2	1495.8	1495.5	1497.3	1496.7	1499.1	1498.4	1500.3	1499.5	1501.7	1501.1	1506.4
	50	1491.9	1496.7	1496.4	1498.5	1497.8	1500.4	1499.7	1501.6	1500.9	1502.9	1502.3	1507.2
	49	1492.6	1497.5	1497.2	1499.1	1498.4	1500.9	1500.2	1502.1	1501.4	1503.3	1502.8	1507.6
	48.10	1492.6	1497.5	1497.2	1499.1	1498.4	1500.9	1500.2	1502.1	1501.4	1503.3	1502.8	1507.6
STINK CREEK		Q=1300CFS	Q=2550	2420	Q=4100	3500	Q=7300	5700	Q=11400	8800	Q=17300	14600	43200
BR SEC 5-6	48	1492.7	1497.6	1497.2	1499.1	1498.4	1500.9	1500.2	1502.1	1501.4	1503.4	1502.8	1507.6
T153N R80W	47.90	1492.7	1497.6	1497.3	1499.2	1498.6	1501.0	1500.3	1502.1	1501.4	1503.4	1502.8	1507.6
	47	1493.2	1498.1	1497.8	1439.6	1499.0	1501.3	1500.6	1502.5	1501.8	1503.8	1503.2	1508.1
	46	1493.6	1498.6	1498.3	1500.2	1499.6	1501.6	1501.0	1502.8	1502.1	1504.2	1503.6	1508.5
	45	1494.3	1499.4	1499.0	1501.2	1500.6	1502.7	1502.0	1503.8	1503.1	1505.1	1504.5	1509.3
	44	1495.1	1500.2	1499.8	1501.9	1501.4	1503.3	1502.7	1504.4	1503.8	1505.7	1505.2	1509.9
	43	1496.9	1501.7	1501.4	1502.7	1502.2	1504.1	1503.5	1505.3	1504.6	1506.6	1506.0	1510.8
	42	1497.6	1502.2	1501.9	1502.9	1502.4	1504.3	1503.7	1505.6	1504.8	1506.9	1506.3	1511.2
	41	1498.2	1502.6	1502.3	1503.1	1502.7	1504.5	1503.9	1505.7	1505.0	1507.1	1506.5	1511.3
	40	1499.0	1503.3	1503.0	1503.6	1503.2	1504.9	1504.3	1506.0	1505.3	1507.4	1506.8	1511.6
	39	1499.4	1503.6	1503.3	1504.1	1503.7	1505.4	1504.8	1506.4	1505.8	1507.7	1507.2	1511.8
	38.93	1499.6	1503.8	1503.5	1504.5	1504.1	1505.7	1505.3	1506.7	1506.3	1508.0	1507.6	1512.0
	38.92	1499.6	1503.9	1503.6	1504.8	1504.3	1506.1	1505.6	1507.2	1506.6	1508.4	1508.0	1512.3
	38.91	1499.7	1504.0	1503.7	1504.9	1504.4	1506.4	1505.8	1507.6	1507.0	1508.9	1508.6	1512.8
	38.90	1499.8	1504.2	1503.9	1505.2	1504.7	1506.9	1506.3	1508.1	1507.6	1509.3	1509.4	1513.1
	38.87	1499.9	1504.3	1503.9	1505.5	1504.9	1507.4	1506.6	1508.9	1508.2	1510.1	1510.1	1513.6
	38.85	1500.0	1504.4	1504.0	1505.7	1504.9	1507.8	1506.7	1509.2	1508.3	1510.3	1510.3	1513.8
	38.80	1500.0	1504.4	1504.0	1505.7	1505.0	1507.9	1506.8	1509.4	1508.5	1510.6	1510.8	1514.4
	38.70	1500.1	1504.5	1504.1	1505.9	1505.1	1508.1	1507.0	1509.6	1508.7	1510.8	1511.1	1514.6
HWY 41 BR	38.65	1500.2	1504.6	1504.1	1505.9	1505.1	1508.1	1506.9	1509.6	1508.7	1510.9	1511.0	1514.7
AT VELVA	38.60	1500.2	1504.6	1504.1	1505.9	1505.1	1508.1	1506.9	1509.6	1508.7	1510.9	1511.7	1522.1
	38.53	1500.2	1504.6	1504.1	1505.9	1505.1	1508.1	1507.0	1509.7	1508.8	1511.0	1512.0	1522.1
	38.52	1500.2	1504.6	1504.1	1506.0	1505.1	1508.3	1507.1	1510.0	1508.9	1511.3	1512.2	1522.2
	38.50	1500.3	1504.7	1504.2	1506.2	1505.2	1508.7	1507.2	1510.3	1509.1	1511.6	1512.5	1522.2
	38.45	1500.4	1504.9	1504.2	1506.5	1505.2	1509.1	1507.2	1510.7	1509.2	1512.0	1512.6	1522.2
	38.40	1500.6	1505.0	1504.2	1506.6	1505.3	1509.3	1507.4	1510.9	1509.4	1512.2	1512.9	1522.3
VELVA LEVEE	38.30	1500.8	1505.1	1504.2	1506.9	1505.3	1509.5	1507.4	1511.1	1509.4	1512.4	1513.0	1522.3

TABLE A-34 (continued, page 5 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL WITH & WITHOUT	5-YR CWSEL WITHOUT PROJECT	5-YR CWSEL WITH PROJECT	10-YR CWSEL WITHOUT PROJECT	10-YR CWSEL WITH PROJECT	25-YR CWSEL WITHOUT PROJECT	25-YR CWSEL WITH PROJECT	50-YR CWSEL WITHOUT PROJECT	50-YR CWSEL WITH PROJECT	100-YR CWSEL WITHOUT PROJECT	100-YR CWSEL WITH PROJECT	500-YR CWSEL WITH PROJECT
VELVA LEVEE	38.22	1500.9	1505.3	1504.2	1507.2	1505.3	1509.7	1507.4	1511.2	1509.4	1512.6	1513.1	1522.3
VELVA PARK BR	38.21	1500.9	1505.3	1504.2	1507.2	1505.3	1509.8	1507.4	1511.3	1509.4	1512.7	1513.0	1522.4
	38.20	1500.9	1505.3	1504.3	1507.2	1505.3	1509.9	1507.4	1511.5	1509.5	1512.8	1513.1	1522.4
	38.19	1500.9	1505.3	1504.3	1507.2	1505.4	1509.9	1507.5	1511.5	1509.6	1512.8	1513.2	1522.4
	38.18	1501.0	1505.5	1504.3	1507.5	1505.4	1510.3	1507.6	1511.8	1509.7	1513.0	1513.4	1522.4
	38.10	1501.4	1505.8	1504.3	1508.0	1505.5	1510.9	1507.6	1512.3	1509.8	1513.5	1513.6	1522.5
	38.05	1501.5	1506.0	1504.4	1508.2	1505.6	1511.2	1507.9	1512.6	1510.3	1513.8	1514.2	1522.5
	38.04	1501.9	1506.4	1504.5	1508.8	1505.7	1511.5	1508.0	1512.8	1510.3	1514.1	1514.2	1522.6
BONNES COULEE		Q=1250CFS	Q=2500	2350	Q=4030	3400	Q=7150	5500	Q=11200	8500	Q=16900	14100	42500
	38.02	1502.1	1506.6	1504.6	1509.1	1505.9	1511.8	1508.3	1513.1	1510.7	1514.4	1514.4	1522.7
	38	1502.2	1506.7	1504.8	1509.3	1506.1	1511.9	1508.6	1513.3	1511.1	1514.6	1514.6	1522.8
	37	1503.2	1507.8	1506.3	1510.7	1508.3	1513.3	1511.4	1514.8	1513.4	1516.1	1515.7	1523.2
	36	1504.0	1508.6	1507.4	1511.5	1509.5	1513.9	1512.3	1515.4	1514.3	1516.9	1516.4	1523.7
	35	1504.4	1509.0	1508.0	1511.7	1510.0	1514.1	1512.6	1515.6	1514.5	1517.1	1516.6	1523.9
	34	1505.8	1510.4	1509.6	1512.8	1511.7	1514.7	1513.7	1516.2	1515.1	1517.6	1517.1	1524.1
	33	1506.7	1511.3	1510.6	1514.0	1512.9	1516.0	1515.2	1517.3	1516.5	1518.6	1518.0	1524.5
	32.50	1507.7	1512.3	1511.6	1514.5	1513.6	1516.4	1515.6	1517.7	1516.8	1519.0	1518.4	1524.8
	32	1509.2	1513.5	1513.0	1514.9	1514.2	1516.7	1515.9	1518.0	1517.1	1519.3	1518.7	1525.0
	31	1510.7	1514.8	1514.4	1516.1	1515.4	1517.6	1517.0	1518.9	1518.0	1520.2	1519.6	1525.5
	30	1511.3	1515.4	1515.0	1516.7	1515.9	1518.2	1517.6	1519.6	1518.7	1520.9	1520.3	1525.9
	29	1512.1	1516.3	1515.8	1517.3	1516.6	1518.9	1518.3	1520.3	1519.4	1521.6	1521.0	1526.4
	28.10	1512.1	1516.4	1515.9	1517.4	1516.7	1519.1	1518.4	1520.4	1519.6	1521.8	1521.1	1526.4
SCHILLING BR	28	1512.1	1516.4	1515.9	1517.4	1516.7	1519.0	1518.4	1520.2	1519.6	1521.5	1520.8	1526.5
	27	1512.3	1516.6	1516.1	1517.9	1517.1	1519.9	1519.1	1521.4	1520.5	1522.6	1522.1	1527.0
	26	1512.8	1517.1	1516.7	1518.8	1517.9	1521.0	1520.1	1522.6	1521.7	1523.9	1523.3	1528.3
	25	1513.8	1518.0	1517.6	1519.8	1519.0	1522.0	1521.0	1523.6	1522.6	1525.0	1524.4	1529.5
	24	1514.6	1518.9	1518.4	1520.8	1520.0	1522.9	1521.9	1524.4	1523.5	1526.0	1525.3	1530.6
	23.90	1514.9	1519.3	1518.8	1521.3	1520.5	1523.3	1522.4	1524.9	1524.0	1526.4	1525.8	1531.1
	23.80	1515.1	1519.5	1519.1	1521.5	1520.8	1523.5	1522.6	1525.0	1524.1	1526.6	1526.0	1531.3
	23.70	1515.2	1519.5	1519.1	1521.5	1520.8	1523.5	1522.7	1525.1	1524.2	1526.6	1526.0	1531.4
FAS 5153 BR	23.60	1515.2	1519.5	1519.1	1521.6	1520.9	1523.6	1522.7	1525.1	1524.3	1526.6	1526.1	1534.2
AT SAWYER	23.61	1515.2	1519.5	1519.1	1521.6	1520.9	1523.6	1522.7	1525.2	1524.3	1526.8	1526.2	1534.3
SAWYER		Q=1230CFS	Q=2450	2300	Q=3950	3300	Q=7000	5300	Q=11000	8300	Q=16700	13900	42100
SAWYER LEVEE	23.50	1515.2	1519.6	1519.1	1521.6	1521.0	1523.7	1522.8	1525.4	1524.5	1527.1	1526.6	1534.6
	23.40	1515.4	1519.8	1519.3	1521.9	1521.2	1524.1	1523.1	1526.0	1525.0	1527.9	1527.5	1535.3
	23.30	1515.9	1520.3	1519.8	1522.5	1521.7	1525.0	1523.9	1526.9	1526.0	1528.8	1528.6	1535.8
SOO LINE RR BR	23.20	1515.9	1520.3	1519.8	1522.5	1521.7	1525.0	1523.9	1527.6	1526.0	1530.3	1529.9	1536.1
	23.10	1516.4	1520.6	1520.2	1523.0	1522.2	1525.6	1524.4	1528.2	1526.7	1530.8	1530.3	1536.6
	23	1516.9	1521.2	1520.7	1523.5	1522.7	1525.9	1524.8	1528.3	1526.8	1530.9	1530.4	1536.7
	22	1517.8	1522.0	1521.6	1524.5	1523.6	1527.1	1525.9	1529.3	1528.0	1531.6	1531.0	1537.3
	21	1518.8	1522.8	1522.4	1525.4	1524.5	1527.7	1526.7	1529.8	1528.5	1531.9	1531.3	1537.7
BR SEC 3	20.10	1518.9	1522.9	1522.5	1525.5	1524.6	1527.7	1526.7	1529.8	1528.5	1532.0	1531.4	1537.7
T153N R81W	20	1518.9	1522.9	1522.5	1525.6	1524.6	1527.8	1526.7	1529.8	1528.6	1532.0	1531.4	1537.9

TABLE A-34 (continued, page 6 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL	5-YR CWSEL		10-YR CWSEL		25-YR CWSEL		50-YR CWSEL		100-YR CWSEL		500-YR CWSEL
		WITH & WITHOUT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITH PROJECT
	19	1519.4	1523.4	1523.0	1526.0	1525.1	1528.3	1527.2	1530.3	1529.0	1532.4	1531.8	1538.3
	18	1520.1	1524.1	1523.7	1526.8	1525.9	1529.5	1528.3	1531.4	1530.2	1533.4	1532.7	1539.0
	17	1521.1	1525.0	1524.6	1527.8	1526.8	1530.8	1529.4	1532.5	1531.5	1534.3	1533.6	1539.6
	16	1521.8	1525.8	1525.4	1528.8	1527.7	1532.1	1530.6	1533.7	1532.7	1535.3	1534.6	1540.3
	15	1522.3	1526.4	1525.9	1529.5	1528.3	1532.8	1531.3	1534.5	1533.5	1536.2	1535.5	1541.3
	14	1522.6	1526.8	1526.4	1530.0	1528.8	1533.2	1531.7	1535.0	1533.9	1536.8	1536.0	1542.0
	13	1523.4	1527.7	1527.2	1531.0	1529.7	1534.0	1532.7	1535.8	1534.7	1537.6	1536.8	1542.8
	12	1523.8	1528.1	1527.6	1531.3	1530.1	1534.2	1533.0	1536.0	1534.9	1537.8	1537.0	1542.9
	10	1524.8	1529.1	1528.7	1532.0	1531.1	1534.5	1533.4	1536.2	1535.1	1538.0	1537.2	1543.2
KEMP COULEE		Q=1210CFS	Q=2400	2250	Q=3870	3200	Q=6900	5200	Q=10800	8000	Q=16400	13500	41700
	9	1525.3	1529.7	1529.3	1532.8	1531.8	1534.9	1533.9	1536.5	1535.5	1538.2	1537.4	1543.4
	8	1525.5	1530.0	1529.6	1533.1	1532.1	1535.4	1534.4	1536.9	1535.9	1538.6	1537.8	1543.6
SOO LINE RR BR	7.10	1525.5	1530.0	1529.6	1533.1	1532.1	1535.3	1534.4	1536.7	1535.9	1538.6	1537.5	1543.6
AT LOGAN	7	1525.5	1530.0	1529.6	1533.1	1532.1	1535.7	1534.6	1537.9	1536.5	1540.4	1539.1	1544.0
	6.90	1525.5	1530.1	1529.6	1533.2	1532.1	1535.8	1534.7	1538.2	1536.7	1540.4	1539.5	1544.0
	6	1526.2	1530.7	1530.2	1533.9	1532.8	1536.2	1535.5	1538.5	1537.1	1540.5	1539.9	1544.1
	5	1526.6	1531.1	1530.7	1534.4	1533.3	1536.3	1535.9	1538.6	1537.2	1540.5	1539.9	1544.1
	4.60	1526.8	1531.3	1530.8	1534.6	1533.4	1536.3	1535.9	1538.5	1537.2	1540.5	1539.9	1544.1
	4.50	1526.8	1531.4	1530.9	1534.7	1533.5	1536.4	1535.9	1538.6	1537.3	1540.5	1539.9	1544.2
	4.40	1526.9	1531.4	1530.9	1534.7	1533.5	1536.4	1536.0	1538.6	1537.3	1540.6	1540.0	1544.2
	4.30	1526.9	1531.4	1530.9	1534.7	1533.5	1536.4	1536.0	1538.6	1537.3	1540.6	1540.0	1544.2
	4.20	1526.9	1531.4	1530.9	1534.8	1533.6	1536.4	1536.0	1538.6	1537.3	1540.6	1540.0	1544.2
	4.10	1526.9	1531.4	1530.9	1534.7	1533.5	1536.4	1536.0	1538.6	1537.3	1540.6	1540.0	1544.2
	4	1527.2	1531.7	1531.2	1534.9	1533.8	1536.7	1536.1	1538.8	1537.5	1540.7	1540.1	1544.4
	3	1528.3	1532.4	1532.0	1535.4	1534.3	1537.3	1536.6	1539.1	1537.9	1541.0	1540.4	1544.8
HWY 14 BR	2.10	1528.3	1532.4	1532.0	1535.4	1534.3	1537.2	1536.5	1539.0	1537.8	1541.0	1540.3	1544.9
AT LOGAN	16	1528.3	1532.4	1532.0	1535.4	1534.3	1537.4	1536.5	1539.2	1537.9	1541.0	1540.4	1544.9
	130	1528.3	1532.5	1532.1	1535.5	1534.4	1537.6	1536.7	1539.7	1538.3	1541.2	1540.6	1545.0
	260	1528.3	1532.5	1532.1	1535.6	1534.5	1537.7	1536.8	1539.8	1538.3	1541.2	1540.6	1545.0
	600	1528.4	1532.6	1532.1	1535.6	1534.5	1537.7	1536.8	1539.8	1538.3	1541.3	1540.7	1545.1
	1400	1528.5	1532.7	1532.3	1535.7	1534.6	1537.8	1536.8	1539.8	1538.4	1541.3	1540.7	1545.1
	2500	1528.7	1532.8	1532.4	1535.7	1534.6	1537.8	1536.9	1539.8	1538.4	1541.3	1540.8	1545.2
RR BR #34	5620	1529.0	1532.9	1532.5	1535.8	1534.7	1537.9	1536.9	1539.9	1538.5	1541.4	1540.8	1545.4
RR BR #33	6000	1529.0	1532.9	1532.5	1535.8	1534.7	1537.9	1536.9	1539.9	1538.5	1541.4	1540.8	1545.4
	6150	1529.0	1532.9	1532.5	1535.8	1534.7	1537.9	1536.9	1539.9	1538.5	1541.5	1540.8	1545.4
	7500	1529.2	1533.1	1532.7	1535.9	1534.9	1538.1	1537.1	1540.1	1538.7	1541.6	1541.0	1545.6
	9025	1529.4	1533.4	1533.0	1536.2	1535.2	1538.6	1537.4	1540.3	1539.0	1541.8	1541.2	1545.8
RR BR #32	9450	1529.4	1533.4	1533.1	1536.3	1535.2	1538.7	1537.5	1540.3	1539.0	1541.8	1541.2	1545.9
	15410	1530.2	1534.2	1533.8	1537.0	1535.9	1539.4	1538.1	1540.8	1539.6	1542.2	1541.7	1546.3
	20465	1531.0	1535.0	1534.6	1537.9	1536.8	1540.1	1538.8	1541.4	1540.2	1542.6	1542.2	1546.7
	23450	1531.6	1535.6	1535.2	1538.6	1537.4	1540.6	1539.2	1541.8	1540.7	1543.0	1542.6	1547.2
	25820	1531.9	1536.1	1535.7	1539.1	1537.9	1540.8	1539.4	1542.0	1540.9	1543.1	1542.9	1547.4
	27235	1532.2	1536.4	1536.0	1539.5	1538.3	1541.0	1539.6	1542.2	1541.1	1543.3	1543.0	1547.6
	29235	1532.5	1536.8	1536.4	1539.9	1538.7	1541.3	1539.8	1542.4	1541.3	1543.5	1543.2	1547.8
	31585	1532.9	1537.3	1536.8	1540.3	1539.1	1541.7	1540.4	1542.8	1541.8	1543.8	1543.7	1548.1

TABLE A-34 (continued, page 7 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL	5-YR CWSEL		10-YR CWSEL		25-YR CWSEL		50-YR CWSEL		100-YR CWSEL		500-YR CWSEL
		WITH & WITHOUT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITH PROJECT
	33080	1533.1	1537.4	1536.9	1540.4	1539.3	1541.9	1540.6	1543.1	1542.0	1544.0	1543.9	1548.3
	33300	1533.1	1537.4	1536.9	1540.4	1539.3	1542.0	1540.6	1543.1	1542.0	1544.0	1544.0	1548.3
	33800	1533.1	1537.4	1537.0	1540.5	1539.3	1542.0	1540.7	1543.3	1542.1	1544.1	1544.1	1548.5
	34470	1533.1	1537.5	1537.0	1540.5	1539.4	1542.2	1540.8	1543.4	1542.3	1544.4	1544.3	1548.7
	34620	1533.1	1537.4	1537.0	1540.5	1539.3	1542.1	1540.7	1543.4	1542.3	1544.4	1544.3	1548.8
TYPE 1 GABION CONTROL STRUC	34849	1533.2	1537.5	1537.1	1540.6	1539.4	1542.3	1540.9	1543.7	1542.5	1544.6	1544.6	1548.9
	34870	1533.2	1537.5	1537.0	1540.6	1539.4	1542.3	1540.9	1543.7	1542.5	1544.6	1544.6	1548.9
	34873	1533.2	1537.5	1537.0	1540.6	1539.4	1542.3	1540.9	1543.7	1542.5	1544.6	1544.6	1548.9
	34894	1533.2	1537.5	1537.1	1540.6	1539.4	1542.3	1540.9	1543.7	1542.5	1544.6	1544.6	1548.9
	35120	1533.2	1537.5	1537.1	1540.6	1539.5	1542.3	1540.9	1543.7	1542.5	1544.6	1544.6	1548.9
	35900	1533.2	1537.6	1537.1	1540.7	1539.5	1542.4	1541.0	1543.8	1542.6	1544.7	1544.7	1549.0
	36170	1533.3	1537.6	1537.1	1540.7	1539.5	1542.4	1541.0	1543.8	1542.6	1544.8	1544.7	1549.0
	36500	1533.3	1537.6	1537.2	1540.7	1539.5	1542.5	1541.1	1544.0	1542.7	1544.9	1544.9	1549.2
	37000	1533.3	1537.6	1537.2	1540.8	1539.6	1542.6	1541.1	1544.0	1542.8	1545.0	1545.0	1549.3
	38000	1533.3	1537.7	1537.2	1540.8	1539.6	1542.7	1541.2	1544.2	1542.9	1545.2	1545.2	1549.5
	39420	1533.4	1537.8	1537.3	1540.9	1539.7	1542.9	1541.3	1544.5	1543.1	1545.5	1545.5	1550.0
	39570	1533.4	1537.8	1537.3	1540.9	1539.7	1543.0	1541.4	1544.5	1543.2	1545.6	1545.5	1550.1
TYPE 1 GABION CONTROL STRUC	39865	1533.4	1537.8	1537.3	1541.0	1539.7	1543.0	1541.4	1544.6	1543.2	1545.6	1545.6	1550.2
	39900	1533.4	1537.8	1537.3	1540.9	1539.7	1543.0	1541.4	1544.5	1543.2	1545.6	1545.5	1550.2
	39909	1533.4	1537.8	1537.3	1540.9	1539.7	1543.0	1541.4	1544.5	1543.2	1545.6	1545.5	1550.2
	39932	1533.4	1537.8	1537.4	1541.0	1539.8	1543.1	1541.5	1544.8	1543.4	1545.9	1545.8	1550.2
	40500	1533.5	1537.9	1537.4	1541.1	1539.8	1543.2	1541.6	1544.9	1543.5	1546.0	1545.9	1550.4
	40818	1533.5	1537.9	1537.4	1541.1	1539.9	1543.3	1541.6	1545.0	1543.6	1546.2	1546.0	1549.6
	40819	1533.5	1537.9	1537.4	1541.1	1539.8	1543.3	1541.6	1544.9	1543.5	1546.0	1545.9	1548.0
	40841	1533.5	1537.9	1537.4	1541.1	1539.9	1543.3	1541.6	1545.0	1543.6	1546.1	1546.0	1548.5
	40842	1533.5	1537.9	1537.5	1541.1	1539.9	1543.3	1541.6	1545.0	1543.6	1546.3	1546.1	1552.8
	40950	1533.5	1537.9	1537.5	1541.1	1539.9	1543.3	1541.7	1545.2	1543.7	1546.6	1546.3	1553.6
	41365	1533.6	1537.9	1537.5	1541.2	1539.9	1543.5	1541.8	1545.4	1543.8	1547.0	1546.6	1554.0
	41400	1533.5	1537.9	1537.5	1541.2	1539.9	1543.5	1541.8	1545.4	1543.8	1547.0	1546.6	1554.0
	41409	1533.5	1537.9	1537.5	1541.2	1539.9	1543.5	1541.8	1545.4	1543.8	1547.0	1546.6	1554.0
	41432	1533.6	1538.0	1537.5	1541.2	1539.9	1543.5	1541.8	1545.4	1543.8	1547.0	1546.6	1554.0
	41580	1533.6	1538.0	1537.5	1541.2	1540.0	1543.5	1541.8	1545.4	1543.9	1547.1	1546.6	1554.0
	41740	1533.6	1538.0	1537.6	1541.3	1540.0	1543.5	1541.8	1545.4	1543.9	1547.1	1546.6	1554.0
	42700	1533.7	1538.1	1537.6	1541.3	1540.0	1543.6	1541.9	1545.6	1544.0	1547.2	1546.8	1554.2
	43240	1533.7	1538.1	1537.6	1541.3	1540.1	1543.7	1541.9	1545.7	1544.1	1547.5	1546.9	1554.3
	43380	1533.7	1538.1	1537.6	1541.3	1540.1	1543.7	1542.0	1545.8	1544.1	1547.7	1547.1	1554.5
TYPE 1 GABION CONTROL STRUC	43569	1533.7	1538.1	1537.6	1541.3	1540.1	1543.7	1542.0	1545.8	1544.1	1547.7	1547.1	1554.5
	43604	1533.7	1538.1	1537.6	1541.3	1540.1	1543.7	1542.0	1545.8	1544.1	1547.7	1547.1	1554.5
	43613	1533.7	1538.1	1537.6	1541.3	1540.1	1543.7	1542.0	1545.8	1544.1	1547.7	1547.1	1554.5
	43636	1533.8	1538.1	1537.7	1541.4	1540.1	1543.8	1542.0	1545.8	1544.2	1547.7	1547.1	1554.5
	43800	1533.8	1538.1	1537.7	1541.4	1540.1	1543.8	1542.0	1545.9	1544.2	1547.8	1547.2	1554.6
	44100	1533.8	1538.2	1537.7	1541.4	1540.2	1543.8	1542.0	1545.9	1544.2	1547.8	1547.2	1554.6
LARSON COULEE		Q=1180CFS	Q=2350	2200	Q=3800	3100	Q=6800	5100	Q=10600	7800	Q=16200	13200	41300
	45000	1533.8	1538.2	1537.8	1541.5	1540.2	1543.9	1542.1	1546.0	1544.3	1547.9	1547.3	1554.7
	45320	1533.8	1538.2	1537.8	1541.5	1540.2	1543.9	1542.1	1546.0	1544.3	1548.0	1547.3	1554.8

TABLE A-34 (continued, page 8 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL WITH & WITHOUT	5-YR CWSEL WITHOUT PROJECT	5-YR CWSEL WITH PROJECT	10-YR CWSEL WITHOUT PROJECT	10-YR CWSEL WITH PROJECT	25-YR CWSEL WITHOUT PROJECT	25-YR CWSEL WITH PROJECT	50-YR CWSEL WITHOUT PROJECT	50-YR CWSEL WITH PROJECT	100-YR CWSEL WITHOUT PROJECT	100-YR CWSEL WITH PROJECT	500-YR CWSEL WITH PROJECT
	45400	1533.8	1538.2	1537.8	1541.5	1540.2	1543.9	1542.1	1546.0	1544.3	1548.0	1547.4	1554.9
	45800	1533.8	1538.3	1537.8	1541.5	1540.2	1543.9	1542.1	1546.1	1544.4	1548.0	1547.4	1554.9
	46280	1533.9	1538.3	1537.8	1541.6	1540.3	1544.0	1542.2	1546.3	1544.5	1548.3	1547.6	1555.1
TYPE 1 GABION	46660	1533.9	1538.3	1537.8	1541.6	1540.3	1544.1	1542.3	1546.3	1544.6	1548.4	1547.7	1555.2
CONTROL STRUC	46695	1533.9	1538.3	1537.8	1541.6	1540.3	1544.1	1542.3	1546.3	1544.6	1548.4	1547.7	1555.2
	46704	1533.9	1538.3	1537.8	1541.6	1540.3	1544.1	1542.3	1546.3	1544.6	1548.4	1547.7	1555.2
	46727	1534.0	1538.3	1537.9	1541.6	1540.3	1544.1	1542.3	1546.4	1544.6	1548.4	1547.7	1555.2
	47370	1534.0	1538.4	1537.9	1541.7	1540.4	1544.2	1542.3	1546.4	1544.7	1548.6	1547.8	1555.3
	47540	1534.0	1538.4	1538.0	1541.8	1540.5	1544.3	1542.4	1546.5	1544.8	1548.6	1547.8	1555.3
	48800	1534.1	1538.5	1538.0	1541.8	1540.5	1544.4	1542.5	1546.6	1544.9	1548.7	1547.9	1555.4
	50000	1534.1	1538.6	1538.1	1541.9	1540.6	1544.5	1542.6	1546.7	1545.0	1548.8	1548.0	1555.5
	50870	1534.2	1538.6	1538.1	1541.9	1540.6	1544.6	1542.7	1546.8	1545.1	1548.9	1548.2	1555.6
	51070	1534.2	1538.6	1538.1	1541.9	1540.6	1544.6	1542.7	1546.8	1545.1	1548.9	1548.1	1555.6
	51146	1534.2	1538.6	1538.1	1541.9	1540.6	1544.5	1542.6	1546.7	1545.0	1548.6	1548.1	1555.2
US HWY #2 BR	51147	1534.2	1538.6	1538.1	1541.9	1540.6	1544.5	1542.6	1546.7	1545.0	1548.5	1548.0	1555.6
	50377	1534.2	1538.6	1538.1	1541.9	1540.6	1544.6	1542.7	1546.8	1545.1	1548.8	1548.2	1555.9
	50378	1534.2	1538.6	1538.2	1542.0	1540.7	1544.7	1542.8	1547.0	1545.2	1549.1	1548.4	1556.8
	50620	1534.3	1538.8	1538.3	1542.1	1540.8	1545.0	1543.0	1547.5	1545.6	1550.0	1549.1	1556.9
	51530	1534.3	1538.8	1538.3	1542.2	1540.8	1545.0	1543.0	1547.6	1545.6	1550.0	1549.1	1556.9
	52425	1534.4	1538.8	1538.4	1542.2	1540.9	1545.1	1543.1	1547.6	1545.7	1550.1	1549.2	1557.0
	53635	1534.4	1538.9	1538.4	1542.3	1540.9	1545.2	1543.2	1547.8	1545.8	1550.2	1549.2	1557.1
TYPE 1 GABION	53803	1534.4	1538.9	1538.4	1542.3	1540.9	1545.2	1543.2	1547.8	1545.8	1550.4	1549.4	1557.2
CONTROL STRUC	53845	1534.4	1538.9	1538.4	1542.3	1540.9	1545.2	1543.2	1547.7	1545.8	1550.4	1549.4	1557.2
	53854	1534.4	1538.9	1538.4	1542.3	1540.9	1545.2	1543.2	1547.7	1545.8	1550.4	1549.4	1557.2
	53880	1534.5	1539.0	1538.5	1542.4	1541.0	1545.3	1543.3	1547.9	1545.9	1550.4	1549.4	1557.2
	53950	1534.6	1539.0	1538.5	1542.4	1541.0	1545.3	1543.3	1547.9	1545.9	1550.4	1549.4	1557.2
	54129	1534.6	1539.0	1538.5	1542.4	1541.1	1545.4	1543.4	1548.1	1546.1	1550.4	1549.4	1557.2
	55370	1534.7	1539.1	1538.6	1542.5	1541.1	1545.5	1543.5	1548.2	1546.2	1550.5	1549.5	1557.3
	56670	1534.7	1539.1	1538.7	1542.6	1541.2	1545.7	1543.6	1548.4	1546.3	1550.7	1549.7	1557.5
LIVINGSTON CREEK		Q=1150CFS	Q=2300	2100	Q=3750	3000	Q=6700	4900	Q=10400	7600	Q=16000	13000	41100
	56770	1534.7	1539.1	1538.7	1542.6	1541.2	1545.7	1543.6	1548.4	1546.3	1550.7	1549.7	1557.5
	57073	1534.8	1539.2	1538.7	1542.6	1541.2	1545.7	1543.7	1548.4	1546.4	1550.7	1549.7	1557.5
27TH ST BR	57074	1534.8	1539.2	1538.7	1542.6	1541.2	1545.7	1543.7	1548.4	1546.4	1550.8	1549.8	1557.6
	57126	1534.8	1539.2	1538.7	1542.6	1541.3	1545.7	1543.7	1548.4	1546.4	1550.9	1549.8	1557.6
	57127	1534.8	1539.2	1538.7	1542.6	1541.3	1545.7	1543.7	1548.4	1546.4	1550.8	1549.8	1557.6
	57220	1534.8	1539.2	1538.7	1542.6	1541.3	1545.7	1543.7	1548.4	1546.4	1550.8	1549.8	1557.6
	57290	1534.8	1539.2	1538.7	1542.6	1541.3	1545.7	1543.7	1548.4	1546.4	1550.8	1549.8	1557.7
	58800	1534.9	1539.4	1538.9	1542.8	1541.4	1546.0	1543.9	1548.9	1546.8	1551.2	1550.2	1557.8
	60400	1535.1	1539.5	1539.1	1543.0	1541.6	1546.3	1544.2	1549.3	1547.1	1551.5	1550.5	1557.9
TYPE 1 GABION	60925	1535.2	1539.6	1539.1	1543.1	1541.7	1546.6	1544.4	1549.7	1547.4	1551.6	1550.5	1558.0
CONTROL STRUC	60985	1536.5	1539.5	1539.0	1543.1	1541.6	1546.6	1544.3	1549.7	1547.3	1551.6	1550.5	1558.0
	60994	1537.2	1539.5	1539.0	1543.1	1541.6	1546.6	1544.3	1549.7	1547.3	1551.6	1550.5	1558.0
	61030	1537.8	1540.0	1539.6	1543.3	1541.9	1546.7	1544.5	1549.7	1547.5	1551.6	1550.5	1558.0
	61500	1537.8	1540.1	1539.6	1543.4	1542.0	1546.7	1544.6	1549.6	1547.4	1551.6	1550.5	1558.0
	62380	1537.9	1540.2	1539.7	1543.5	1542.1	1546.8	1544.7	1549.8	1547.6	1551.7	1550.6	1558.1

TABLE A-34 (continued, page 9 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL WITH & WITHOUT	5-YR CWSEL WITHOUT PROJECT	5-YR CWSEL WITH PROJECT	10-YR CWSEL WITHOUT PROJECT	10-YR CWSEL WITH PROJECT	25-YR CWSEL WITHOUT PROJECT	25-YR CWSEL WITH PROJECT	50-YR CWSEL WITHOUT PROJECT	50-YR CWSEL WITH PROJECT	100-YR CWSEL WITHOUT PROJECT	100-YR CWSEL WITH PROJECT	500-YR CWSEL WITH PROJECT
	62420	1537.9	1540.2	1539.7	1543.5	1542.1	1546.9	1544.7	1549.9	1547.7	1551.8	1550.7	1558.1
	62488	1537.9	1540.2	1539.7	1543.5	1542.1	1546.9	1544.7	1549.9	1547.7	1551.8	1550.7	1558.1
8TH AVE SE BR	62489	1537.9	1540.2	1539.7	1543.5	1542.1	1546.9	1544.7	1549.9	1547.7	1551.8	1550.7	1558.3
	62523	1537.9	1540.2	1539.7	1543.5	1542.1	1546.9	1544.7	1549.9	1547.7	1551.9	1550.8	1558.3
	62524	1537.9	1540.2	1539.7	1543.5	1542.1	1546.9	1544.8	1550.0	1547.7	1551.8	1550.8	1558.3
	62600	1537.9	1540.2	1539.7	1543.6	1542.1	1546.9	1544.8	1550.0	1547.7	1551.9	1550.9	1558.3
	62660	1537.9	1540.2	1539.7	1543.6	1542.1	1546.9	1544.8	1550.0	1547.7	1551.9	1550.9	1558.3
	64630	1538.0	1540.4	1540.0	1543.8	1542.4	1547.3	1545.1	1550.5	1548.1	1552.5	1551.4	1558.6
	64690	1538.0	1540.5	1540.0	1543.8	1542.4	1547.4	1545.1	1550.6	1548.2	1552.5	1551.5	1558.6
	64802	1538.0	1540.5	1540.0	1543.9	1542.4	1547.4	1545.2	1550.6	1548.2	1552.5	1551.5	1558.6
4TH AVE SE BR	64803	1538.0	1540.5	1540.0	1543.9	1542.4	1547.4	1545.2	1550.6	1548.2	1552.6	1551.5	1558.7
	64843	1538.0	1540.5	1540.0	1543.9	1542.4	1547.4	1545.2	1550.6	1548.2	1552.6	1551.6	1558.7
	64850	1538.0	1540.5	1540.0	1543.9	1542.4	1547.4	1545.2	1550.7	1548.2	1552.6	1551.5	1558.7
ROOSEVELT PARK	65014	1538.1	1540.5	1540.1	1543.9	1542.5	1547.5	1545.3	1550.8	1548.3	1552.6	1551.6	1558.7
CONTROL STRUC	65058	1538.1	1540.5	1540.1	1543.9	1542.5	1547.5	1545.3	1550.8	1548.3	1552.6	1551.6	1558.7
	65059	1539.7	1540.4	1540.3	1543.8	1542.3	1547.4	1545.1	1550.7	1548.2	1552.6	1551.6	1558.7
	65061	1539.9	1540.6	1540.5	1543.8	1542.3	1547.4	1545.1	1550.7	1548.2	1552.6	1551.6	1558.7
	65062	1540.3	1541.3	1541.2	1544.0	1542.6	1547.6	1545.3	1550.9	1548.4	1552.6	1551.6	1558.7
	65533	1540.3	1541.3	1541.2	1544.0	1542.6	1547.6	1545.3	1550.9	1548.4	1552.7	1551.6	1558.7
	66340	1540.4	1541.5	1541.3	1544.2	1542.8	1547.8	1545.5	1551.1	1548.6	1552.8	1551.8	1558.8
	67059	1540.4	1541.6	1541.5	1544.4	1542.9	1548.0	1545.8	1551.3	1548.9	1552.9	1551.9	1559.0
1ST AVE SE BP	67060	1540.4	1541.6	1541.4	1544.4	1542.9	1548.0	1545.7	1551.3	1548.9	1553.2	1552.1	1559.1
	67070	1540.4	1541.6	1541.4	1544.4	1542.9	1548.0	1545.8	1551.3	1548.9	1553.2	1552.1	1559.1
	67071	1540.4	1541.7	1541.5	1544.4	1543.0	1548.1	1545.8	1551.4	1548.9	1553.1	1552.1	1559.0
	67165	1540.5	1541.7	1541.5	1544.5	1543.0	1548.1	1545.9	1551.5	1549.0	1553.2	1552.2	1559.1
	68200	1540.5	1541.9	1541.7	1544.7	1543.2	1548.4	1546.1	1551.8	1549.3	1553.4	1552.4	1559.1
	68970	1540.6	1542.0	1541.8	1544.8	1543.4	1548.6	1546.3	1551.9	1549.5	1553.6	1552.6	1559.2
	69323	1540.6	1542.1	1541.9	1545.0	1543.5	1548.8	1546.5	1552.2	1549.7	1553.8	1552.8	1559.3
	69368	1540.6	1542.1	1541.9	1545.0	1543.5	1548.8	1546.5	1552.2	1549.7	1553.8	1552.8	1559.3
8TH ST NE	69369	1541.2	1541.8	1541.7	1544.9	1543.3	1548.7	1546.4	1552.1	1549.7	1553.8	1552.8	1559.3
CONTROL STRUC	69371	1541.5	1542.4	1542.3	1544.9	1543.3	1548.8	1546.4	1552.1	1549.7	1553.8	1552.8	1559.3
	69372	1542.0	1543.1	1542.9	1545.2	1543.9	1549.0	1546.7	1552.3	1549.9	1553.8	1552.9	1559.3
	69410	1542.0	1543.1	1542.9	1545.3	1543.9	1549.0	1546.7	1552.3	1550.0	1553.9	1552.9	1559.3
	69730	1542.0	1543.1	1542.9	1545.2	1543.9	1549.0	1546.7	1552.3	1549.9	1553.9	1552.9	1559.3
	70400	1542.0	1543.2	1543.0	1545.4	1544.0	1549.2	1546.8	1552.4	1550.1	1554.0	1553.1	1559.4
	70819	1542.0	1543.3	1543.1	1545.4	1544.1	1549.3	1546.9	1552.5	1550.2	1554.1	1553.1	1559.5
1ST AVE NE BR	70820	1542.0	1543.2	1543.0	1545.4	1544.1	1549.2	1546.9	1552.4	1550.1	1554.2	1553.1	1559.7
	70860	1542.0	1543.3	1543.1	1545.4	1544.1	1549.3	1546.9	1552.5	1550.2	1554.3	1553.3	1559.7
	70861	1542.1	1543.3	1543.1	1545.5	1544.2	1549.4	1547.0	1553.1	1550.3	1554.3	1553.4	1559.7
	70960	1542.1	1543.3	1543.1	1545.5	1544.2	1549.4	1547.1	1553.2	1550.4	1554.4	1553.5	1559.7
	71330	1542.1	1543.4	1543.2	1545.6	1544.3	1549.6	1547.2	1553.3	1550.6	1554.6	1553.7	1559.8
	71745	1542.1	1543.4	1543.2	1545.7	1544.4	1549.7	1547.3	1553.4	1550.7	1554.7	1553.8	1559.7
BN RR BR	71746	1542.1	1543.4	1543.2	1545.7	1544.3	1549.6	1547.3	1553.3	1550.6	1554.4	1553.6	1560.6
	71824	1542.1	1543.5	1543.3	1545.8	1544.4	1549.7	1547.3	1553.5	1550.7	1554.9	1553.9	1560.9
	71825	1542.1	1543.5	1543.3	1545.8	1544.5	1549.8	1547.4	1553.9	1550.8	1556.1	1554.6	1560.7
	71880	1542.1	1543.6	1543.3	1545.9	1544.5	1549.8	1547.4	1554.0	1550.9	1556.3	1554.7	1561.4
	71967	1542.2	1543.6	1543.3	1545.9	1544.5	1549.9	1547.5	1554.0	1550.9	1556.4	1554.8	1561.4

TABLE A-34 (continued, page 10 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL	5-YR CWSEL		10-YR CWSEL		25-YR CWSEL		50-YR CWSEL		100-YR CWSEL		500-YR CWSEL
		WITH & WITHOUT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITH PROJECT
3RD ST BR	71968	1542.2	1543.6	1543.3	1545.9	1544.5	1549.9	1547.5	1554.0	1550.9	1556.4	1554.8	1561.5
	72009	1542.2	1543.6	1543.3	1545.9	1544.5	1549.9	1547.5	1554.0	1550.9	1556.4	1554.8	1561.5
	72010	1542.2	1543.6	1543.3	1545.9	1544.5	1549.9	1547.5	1554.0	1550.9	1556.4	1554.8	1561.5
	72110	1542.2	1543.6	1543.4	1545.9	1544.6	1549.9	1547.5	1554.2	1550.9	1556.6	1555.0	1561.5
	72300	1542.2	1543.6	1543.4	1546.0	1544.6	1550.0	1547.6	1554.2	1551.0	1556.8	1555.1	1561.5
	72545	1542.2	1543.7	1543.4	1546.1	1544.7	1550.1	1547.7	1554.3	1551.1	1557.0	1555.3	1561.6
	72700	1542.2	1543.8	1543.5	1546.1	1544.8	1550.2	1547.8	1554.3	1551.2	1557.0	1555.3	1561.6
FOOT BR	72913	1542.3	1543.8	1543.5	1546.2	1544.8	1550.3	1547.8	1554.4	1551.3	1557.1	1555.4	1561.7
	72914	1542.3	1543.8	1543.5	1546.2	1544.8	1550.3	1547.8	1554.5	1551.3	1557.2	1555.5	1561.9
	72927	1542.3	1543.8	1543.5	1546.2	1544.8	1550.3	1547.8	1554.5	1551.3	1557.2	1555.5	1561.9
	72928	1542.3	1543.8	1543.6	1546.2	1544.8	1550.3	1547.8	1554.5	1551.3	1557.1	1555.5	1561.8
	73040	1542.3	1543.8	1543.6	1546.3	1544.9	1550.3	1547.9	1554.5	1551.4	1557.2	1555.5	1561.9
	73700	1542.3	1544.0	1543.7	1546.4	1545.0	1550.6	1548.1	1554.6	1551.6	1557.3	1555.7	1562.1
	74109	1542.4	1544.1	1543.8	1546.6	1545.2	1550.8	1548.3	1554.8	1551.8	1557.4	1555.8	1562.1
BROADWAY BR	74110	1542.4	1544.1	1543.8	1546.6	1545.2	1550.7	1548.3	1554.8	1551.8	1557.4	1555.8	1562.2
	74200	1542.4	1544.1	1543.8	1546.6	1545.2	1550.8	1548.3	1554.8	1551.8	1557.4	1555.8	1562.3
	74201	1542.4	1544.1	1543.9	1546.7	1545.2	1550.8	1548.4	1554.9	1551.9	1557.4	1555.8	1562.2
	74300	1542.4	1544.2	1543.9	1546.7	1545.3	1550.9	1548.4	1555.1	1552.0	1557.5	1555.9	1562.3
	75149	1542.4	1544.2	1543.9	1546.7	1545.3	1550.9	1548.4	1555.1	1552.0	1557.5	1555.9	1562.4
	75300	1542.4	1544.2	1543.9	1546.8	1545.3	1550.9	1548.5	1555.1	1552.0	1557.5	1556.0	1562.4
	75814	1542.5	1544.3	1544.0	1546.9	1545.5	1551.1	1548.6	1555.1	1552.2	1557.6	1556.0	1562.5
4TH AVE NW BR	75815	1542.5	1544.3	1544.0	1546.9	1545.5	1551.1	1548.6	1555.5	1552.1	1557.7	1556.1	1562.6
	75885	1542.5	1544.4	1544.1	1546.9	1545.5	1551.2	1548.7	1555.5	1552.3	1557.7	1556.1	1562.6
	75886	1542.5	1544.4	1544.1	1547.0	1545.5	1551.2	1548.7	1555.5	1552.4	1557.7	1556.1	1562.6
	76800	1542.6	1544.6	1544.3	1547.3	1545.8	1551.5	1549.0	1555.6	1552.6	1557.8	1556.3	1562.7
	77700	1542.8	1544.9	1544.6	1547.6	1546.1	1551.8	1549.3	1555.7	1552.9	1557.8	1556.3	1562.8
	77865	1542.8	1545.0	1544.6	1547.7	1546.2	1551.9	1549.4	1555.7	1552.9	1557.8	1556.4	1562.8
8TH ST NW BR	77866	1542.8	1545.0	1544.6	1547.6	1546.2	1551.9	1549.4	1555.7	1552.9	1557.9	1556.4	1562.9
	77904	1542.8	1545.0	1544.6	1547.7	1546.2	1551.9	1549.4	1555.8	1552.9	1557.9	1556.4	1562.9
	77905	1542.9	1545.0	1544.7	1547.7	1546.3	1551.9	1549.5	1555.7	1552.9	1557.9	1556.4	1562.8
	78000	1542.8	1545.0	1544.6	1547.7	1546.2	1551.9	1549.4	1555.8	1552.9	1557.9	1556.4	1562.9
	78360	1542.9	1545.1	1544.8	1547.8	1546.4	1552.1	1549.6	1555.8	1553.0	1557.9	1556.5	1562.9
	78650	1543.0	1545.4	1545.0	1548.1	1546.6	1552.4	1549.9	1555.9	1553.3	1558.0	1556.6	1562.9
	78692	1543.0	1545.4	1545.0	1548.1	1546.6	1552.4	1549.9	1555.9	1553.3	1558.0	1556.6	1562.9
RAMSTAD PARK	78693	1543.2	1545.2	1544.8	1548.0	1546.5	1552.3	1549.8	1555.9	1553.3	1558.0	1556.6	1562.9
CONTROL STRUC	78695	1543.5	1545.2	1544.8	1548.0	1546.5	1552.3	1549.8	1555.9	1553.3	1558.0	1556.6	1562.9
	78696	1544.0	1545.6	1545.2	1548.2	1546.8	1552.5	1550.0	1555.9	1553.4	1558.0	1556.6	1562.9
	78750	1544.0	1545.6	1545.2	1548.3	1546.8	1552.5	1550.0	1555.9	1553.4	1558.0	1556.6	1562.9
	79100	1544.0	1545.6	1545.2	1548.2	1546.8	1552.5	1550.0	1555.9	1553.4	1558.0	1556.6	1563.0
	79750	1544.1	1545.8	1545.4	1548.5	1547.1	1552.7	1550.3	1556.0	1553.6	1558.1	1556.7	1563.1
	79759	1544.1	1545.8	1545.5	1548.5	1547.1	1552.8	1550.3	1556.0	1553.7	1558.1	1556.7	1563.1
	79760	1544.1	1545.8	1545.5	1548.5	1547.1	1552.8	1550.3	1556.1	1553.7	1558.2	1556.8	1563.1
3RD AVE NW BR	79822	1544.2	1545.9	1545.6	1548.6	1547.2	1552.9	1550.4	1556.1	1553.8	1558.2	1556.8	1563.1
	79823	1544.2	1545.9	1545.6	1548.6	1547.2	1553.0	1550.4	1556.1	1553.8	1558.2	1556.8	1563.1
	80030	1544.2	1546.0	1545.6	1548.8	1547.3	1553.1	1550.6	1556.1	1553.9	1558.2	1556.8	1563.1
	80051	1544.2	1546.0	1545.6	1548.8	1547.3	1553.1	1550.6	1556.1	1553.9	1558.2	1556.8	1563.1
	80052	1544.2	1546.0	1545.7	1548.8	1547.3	1553.1	1550.6	1556.1	1553.9	1558.2	1556.8	1563.1

TABLE A-34 (continued, page 11 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CUSEL	5-YR CUSEL		10-YR CUSEL		25-YR CUSEL		50-YR CUSEL		100-YR CUSEL		500-YR CUSEL
		WITH & WITHOUT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITH PROJECT
	80074	1544.2	1546.0	1545.7	1548.8	1547.3	1553.1	1550.6	1556.1	1553.9	1558.2	1556.8	1563.1
OAK PARK CONTROL STRUC	80075	1543.9	1545.9	1545.5	1548.7	1547.2	1553.1	1550.5	1556.1	1553.9	1558.2	1556.8	1563.2
	80078	1544.3	1545.9	1545.5	1548.7	1547.2	1553.1	1550.5	1556.1	1553.9	1558.2	1556.8	1563.2
	80079	1544.7	1546.3	1545.9	1548.9	1547.5	1553.2	1550.7	1556.1	1554.0	1558.2	1556.8	1563.1
	80083	1544.7	1546.3	1545.9	1548.9	1547.5	1553.2	1550.7	1556.1	1554.0	1558.2	1556.8	1563.1
	80390	1544.7	1546.3	1545.9	1548.9	1547.5	1553.2	1550.7	1556.1	1554.0	1558.2	1556.8	1563.2
	82420	1545.1	1547.0	1546.6	1549.7	1548.3	1553.9	1551.5	1556.5	1554.8	1558.4	1557.2	1563.3
	82474	1545.1	1547.0	1546.7	1549.8	1548.4	1554.0	1551.6	1556.6	1554.8	1558.5	1557.3	1563.3
2ND AVE SW BR	82475	1545.1	1547.0	1546.7	1549.8	1548.3	1554.0	1551.6	1556.6	1554.8	1558.7	1557.4	1563.4
	82526	1545.1	1547.1	1546.7	1549.8	1548.4	1554.1	1551.6	1556.7	1554.9	1558.8	1557.5	1563.4
	82527	1545.1	1547.1	1546.7	1549.8	1548.4	1554.2	1551.6	1556.8	1555.0	1558.7	1557.5	1563.4
	82680	1545.1	1547.1	1546.8	1549.9	1548.5	1554.3	1551.7	1556.9	1555.1	1558.8	1557.6	1563.4
	82822	1545.2	1547.2	1546.8	1549.9	1548.5	1554.3	1551.8	1556.9	1555.2	1558.7	1557.6	1563.3
SOO LINE RR BR	82823	1545.1	1547.2	1546.8	1549.9	1548.5	1554.3	1551.7	1556.8	1555.1	1558.6	1557.5	1563.6
	82837	1545.1	1547.2	1546.8	1549.9	1548.5	1554.3	1551.8	1556.9	1555.1	1558.6	1557.5	1563.7
	82838	1545.2	1547.2	1546.8	1550.0	1548.5	1554.4	1551.8	1557.0	1555.2	1559.1	1557.8	1563.5
	82880	1545.2	1547.2	1546.8	1550.0	1548.5	1554.4	1551.8	1557.0	1555.2	1559.3	1557.8	1564.0
	83070	1545.2	1547.3	1546.9	1550.0	1548.6	1554.4	1551.8	1557.1	1555.3	1559.4	1557.9	1564.1
	83700	1545.3	1547.4	1547.0	1550.2	1548.8	1554.6	1552.0	1557.4	1555.5	1559.7	1558.3	1564.1
	84500	1545.4	1547.6	1547.2	1550.4	1549.0	1554.8	1552.3	1557.5	1555.7	1559.9	1558.5	1564.2
	85704	[illegible]	1548.0	1547.6	1550.9	1549.4	1555.3	1552.8	1558.0	1556.2	1560.3	1558.9	1564.4
NEW RIVER RD BR	85705	1545.6	1548.0	1547.6	1550.9	1549.4	1555.3	1552.8	1558.1	1556.2	1560.4	1559.0	1564.4
	85734	1545.7	1548.1	1547.6	1550.9	1549.5	1555.4	1552.8	1558.1	1556.3	1560.4	1559.0	1564.4
	85735	1545.7	1548.2	1547.8	1551.1	1549.6	1555.5	1553.0	1558.0	1556.3	1560.3	1559.0	1564.4
	85791	1545.7	1548.2	1547.7	1551.1	1549.6	1555.5	1553.1	1558.1	1556.4	1560.4	1559.1	1564.4
	91.10	1545.7	1548.1	1547.7	1551.1	1549.6	1555.5	1553.0	1558.1	1556.3	1560.4	1559.1	1564.4
	92.10	1545.7	1548.1	1547.7	1551.1	1549.6	1555.5	1553.0	1558.1	1556.3	1560.4	1559.1	1564.4
	92.20	1545.7	1548.2	1547.8	1551.2	1549.7	1555.6	1553.1	1558.1	1556.4	1560.4	1559.1	1564.4
	95.30	1545.7	1548.2	1547.8	1551.2	1549.7	1555.6	1553.1	1558.1	1556.4	1560.4	1559.1	1564.4
	95.50	1545.7	1548.2	1547.8	1551.1	1549.7	1555.6	1553.1	1558.2	1556.4	1560.4	1559.1	1564.4
	85797	1545.7	1548.2	1547.8	1551.1	1549.7	1555.6	1553.1	1558.2	1556.4	1560.4	1559.1	1564.4
	97.10	1545.8	1548.3	1547.8	1551.2	1549.7	1555.6	1553.1	1558.2	1556.4	1560.4	1559.1	1564.4
	85808	1545.8	1548.3	1547.8	1551.2	1549.7	1555.6	1553.1	1558.2	1556.4	1560.4	1559.1	1564.4
WATER PLANT DAM	85809	1547.7	1548.8	1548.6	1550.8	1549.3	1555.5	1552.9	1558.1	1556.3	1560.4	1559.1	1564.4
	11.50	1548.2	1549.4	1549.2	1550.8	1550.0	1555.5	1552.9	1558.1	1556.3	1560.4	1559.1	1564.4
	12.50	1548.9	1550.4	1550.2	1552.0	1551.2	1555.9	1553.7	1558.3	1556.6	1560.4	1559.1	1564.4
	85833	1548.9	1550.4	1550.2	1552.0	1551.2	1555.9	1553.7	1558.3	1556.6	1560.4	1559.1	1564.4
	86390	1548.9	1550.5	1550.2	1552.1	1551.3	1556.0	1553.8	1558.3	1556.7	1560.5	1559.1	1564.5
	87480	1549.0	1550.7	1550.4	1552.4	1551.6	1556.3	1554.2	1558.6	1557.1	1560.7	1559.5	1564.7
	87800	1549.0	1550.7	1550.4	1552.5	1551.6	1556.6	1554.3	1558.9	1557.3	1560.8	1559.6	1564.7
	88230	1549.2	1551.1	1550.8	1552.9	1552.0	1556.7	1554.7	1559.0	1557.4	1560.9	1559.6	1564.7
	89060	1549.4	1551.5	1551.1	1553.4	1552.5	1556.9	1555.0	1559.2	1557.6	1561.0	1559.7	1564.8
	89330	1549.5	1551.6	1551.3	1553.6	1552.7	1556.9	1555.1	1559.2	1557.6	1561.0	1559.8	1564.8
GOLF COURSE BR	89331	1549.5	1551.6	1551.3	1553.5	1552.6	1557.0	1555.0	1559.2	1557.7	1561.0	1559.8	1564.9
	89338	1549.5	1551.6	1551.3	1553.6	1552.7	1557.0	1555.0	1559.2	1557.7	1561.0	1559.8	1564.9
	89339	1549.5	1551.6	1551.3	1553.6	1552.7	1557.0	1555.3	1559.2	1557.7	1561.0	1559.8	1564.8
	90180	1549.6	1551.9	1551.5	1554.1	1553.0	1557.2	1555.8	1559.4	1557.8	1561.1	1559.9	1565.0

TABLE A-34 (continued, page 12 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL WITH & WITHOUT	5-YR CWSEL WITHOUT PROJECT	5-YR CWSEL WITH PROJECT	10-YR CWSEL WITHOUT PROJECT	10-YR CWSEL WITH PROJECT	25-YR CWSEL WITHOUT PROJECT	25-YR CWSEL WITH PROJECT	50-YR CWSEL WITHOUT PROJECT	50-YR CWSEL WITH PROJECT	100-YR CWSEL WITHOUT PROJECT	100-YR CWSEL WITH PROJECT	500-YR CWSEL WITH PROJECT
GOLF COURSE BR	90181	1549.6	1551.9	1551.5	1554.1	1553.0	1557.2	1555.8	1559.5	1557.9	1561.1	1559.9	1565.0
	90188	1549.6	1551.9	1551.5	1554.1	1553.0	1557.3	1555.8	1559.5	1557.9	1561.1	1559.9	1565.0
	90189	1549.6	1551.9	1551.5	1554.1	1553.0	1557.2	1555.8	1559.4	1557.9	1561.1	1559.9	1565.0
	90930	1549.7	1552.1	1551.7	1554.4	1553.3	1557.5	1556.2	1559.7	1558.1	1561.2	1560.0	1565.1
BR SEC 23	90931	1549.7	1552.1	1551.7	1554.4	1553.3	1557.3	1556.2	1559.8	1558.2	1561.2	1560.1	1565.2
T155N R82-83W	90941	1549.6	1552.1	1551.7	1554.3	1553.3	1557.3	1556.2	1559.8	1558.2	1561.2	1560.1	1565.2
	90942	1549.6	1552.1	1551.8	1554.5	1553.4	1557.3	1556.3	1559.7	1558.2	1561.1	1560.1	1565.1
	92910	1549.8	1552.4	1552.1	1554.9	1553.8	1557.6	1556.8	1560.0	1558.5	1561.5	1560.5	1565.5
BR SEC 22	92911	1549.8	1552.4	1552.0	1554.9	1553.7	1557.6	1556.7	1560.1	1558.5	1561.6	1560.5	1565.6
T155N R83W	92918	1549.8	1552.4	1552.0	1554.9	1553.7	1557.6	1556.7	1560.1	1558.5	1561.6	1560.5	1565.6
	92919	1549.8	1552.5	1552.1	1555.0	1553.8	1557.6	1556.9	1560.0	1558.5	1561.6	1560.5	1565.5
	93830	1549.9	1552.7	1552.3	1555.3	1554.1	1557.8	1557.3	1560.2	1558.7	1561.7	1560.7	1565.7
	94060	1550.0	1552.8	1552.4	1555.4	1554.2	1557.9	1557.4	1560.3	1558.7	1561.7	1560.7	1565.7
BR SEC 21-22	95009	1550.1	1552.9	1552.5	1555.6	1554.3	1558.0	1557.6	1560.3	1558.8	1561.8	1560.8	1564.8
T155N R83W	95010	1550.1	1552.9	1552.5	1555.6	1554.3	1558.0	1557.6	1560.3	1558.8	1561.7	1560.8	1564.7
	95055	1550.1	1552.9	1552.5	1555.6	1554.3	1558.0	1557.6	1560.3	1558.8	1561.8	1560.8	1565.1
	95056	1550.1	1552.9	1552.5	1555.6	1554.3	1558.1	1557.6	1560.4	1558.9	1561.8	1560.8	1565.5
	95300	1550.1	1553.0	1552.5	1555.6	1554.3	1558.1	1557.6	1560.6	1558.9	1562.5	1561.2	1568.7
	95550	1550.1	1553.0	1552.6	1555.7	1554.4	1558.2	1557.7	1560.6	1559.0	1562.6	1561.2	1568.8
	95685	1550.1	1553.0	1552.6	1555.7	1554.4	1558.2	1557.7	1560.7	1559.1	1562.6	1561.3	1568.8
TIERRECITO	95726	1550.0	1552.9	1552.5	1555.6	1554.3	1558.2	1557.6	1560.6	1559.0	1562.6	1561.3	1568.8
VALLEJO	95735	1550.1	1553.0	1552.5	1555.6	1554.4	1558.2	1557.6	1560.6	1559.0	1562.6	1561.3	1568.8
	95761	1550.3	1553.2	1552.7	1555.8	1554.6	1558.4	1557.8	1560.9	1559.3	1562.7	1561.6	1568.8
	96000	1550.3	1553.2	1552.8	1555.9	1554.6	1558.5	1557.9	1560.9	1559.3	1562.8	1561.7	1568.9
	97280	1550.6	1553.6	1553.1	1556.3	1555.0	1559.2	1558.3	1561.7	1560.1	1563.3	1562.7	1569.2
	98140	1550.8	1553.9	1553.4	1556.8	1555.4	1559.7	1558.7	1562.0	1560.5	1563.6	1563.1	1569.4
	99560	1550.9	1554.2	1553.7	1557.0	1555.6	1559.9	1558.9	1562.2	1560.7	1563.9	1563.4	1569.7
	101324	1551.6	1554.9	1554.4	1557.9	1556.5	1560.9	1559.8	1563.0	1561.6	1564.4	1563.9	1570.1
	101484	1551.7	1555.0	1554.5	1557.9	1556.6	1560.9	1559.8	1563.0	1561.6	1564.4	1563.9	1570.0
SOO LINE RR BR	101485	1551.6	1555.0	1554.5	1557.9	1556.5	1560.9	1559.8	1562.9	1561.6	1564.1	1563.7	1570.5
U/S OF MINOT	101515	1551.7	1555.0	1554.5	1558.0	1556.6	1560.9	1559.8	1563.0	1561.6	1564.4	1563.9	1570.5
	101516	1551.7	1555.1	1554.6	1558.0	1556.6	1561.0	1559.9	1563.3	1561.8	1565.3	1564.4	1570.4
	101616	1551.8	1555.1	1554.6	1558.1	1556.7	1561.2	1560.0	1563.6	1562.0	1566.0	1564.9	1570.8
	104430	1553.0	1556.4	1555.9	1559.4	1558.0	1562.7	1561.3	1565.1	1563.4	1567.6	1566.4	1571.2
	106090	1553.7	1557.1	1556.6	1560.2	1558.8	1563.3	1562.1	1565.6	1564.0	1567.9	1566.8	1571.6
	108700	1554.4	1558.0	1557.4	1561.2	1559.8	1564.3	1563.1	1566.3	1564.9	1568.5	1567.4	1572.0
GASSMAN CREEK		Q=1150CFS	Q=2300	2100	Q=3750	3000	Q=6700	4900	Q=10400	7600	Q=16000	13000	41100
	111000	1554.9	1558.7	1558.1	1561.9	1560.5	1565.1	1563.8	1566.9	1565.7	1568.9	1567.9	1572.3
	112080	1555.1	1559.0	1558.4	1562.2	1560.8	1565.4	1564.1	1567.2	1565.9	1569.1	1568.1	1572.5
	112570	1555.2	1559.1	1558.5	1562.4	1561.0	1565.4	1564.2	1567.2	1566.0	1569.1	1568.1	1572.6
	113680	1555.5	1559.4	1558.8	1562.7	1561.3	1565.5	1564.5	1567.3	1566.0	1569.2	1568.2	1572.7
	114250	1555.6	1559.5	1558.9	1562.8	1561.3	1565.5	1564.6	1567.3	1566.1	1569.2	1568.2	1572.8
	114289	1555.6	1559.5	1558.9	1562.8	1561.3	1565.4	1564.6	1567.2	1566.0	1569.1	1568.1	1572.8
BOY SCOUT BR	114290	1555.6	1559.5	1558.9	1562.8	1561.3	1565.4	1564.6	1567.2	1566.0	1569.3	1568.2	1572.9
	114310	1555.6	1559.5	1558.9	1562.8	1561.3	1565.4	1564.6	1567.2	1566.0	1569.3	1568.3	1572.9

TABLE A-34 (continued, page 13 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CUSEL WITH & WITHOUT	5-YR CUSEL WITHOUT PROJECT	5-YR CUSEL WITH PROJECT	10-YR CUSEL WITHOUT PROJECT	10-YR CUSEL WITH PROJECT	25-YR CUSEL WITHOUT PROJECT	25-YR CUSEL WITH PROJECT	50-YR CUSEL WITHOUT PROJECT	50-YR CUSEL WITH PROJECT	100-YR CUSEL WITHOUT PROJECT	100-YR CUSEL WITH PROJECT	500-YR CUSEL WITH PROJECT
	114311	1555.6	1559.5	1558.9	1562.8	1561.3	1565.4	1564.6	1567.2	1566.0	1569.2	1568.2	1572.8
	114350	1555.6	1559.5	1558.9	1562.8	1561.3	1565.6	1564.6	1567.5	1566.2	1569.4	1568.5	1573.0
	116220	1556.0	1559.9	1559.3	1563.3	1561.8	1566.0	1565.1	1567.8	1566.6	1569.7	1568.8	1573.3
	117390	1556.3	1560.3	1559.7	1563.6	1562.1	1566.2	1565.5	1568.0	1566.8	1569.8	1568.9	1573.5
	121000	1557.5	1561.4	1560.8	1564.3	1563.0	1566.7	1566.0	1568.4	1567.2	1570.2	1569.3	1573.9
	122070	1557.8	1561.7	1561.2	1564.6	1563.3	1566.8	1566.1	1568.5	1567.3	1570.3	1569.4	1574.1
KINGS COURT &	124330	1558.4	1562.3	1561.7	1565.0	1563.7	1567.1	1566.4	1568.7	1567.6	1570.5	1569.7	1574.3
ROSTAD'S ADD.	126000	1558.6	1562.6	1562.0	1565.5	1564.0	1567.3	1566.6	1568.9	1567.9	1570.6	1570.0	1574.6
	129300	1559.3	1563.3	1562.7	1566.4	1564.6	1567.8	1567.0	1569.4	1568.4	1571.1	1570.5	1575.1
COUNTRY CLUB &	132140	1560.1	1564.0	1563.4	1567.1	1565.4	1568.5	1568.0	1570.2	1569.8	1571.7	1571.9	1575.8
ROBINWOOD	134050	1560.4	1564.4	1563.8	1567.4	1565.8	1568.6	1568.5	1570.3	1570.5	1571.9	1573.1	1576.0
TALBOT'S NUR.	135580	1560.7	1564.7	1564.1	1567.7	1566.1	1568.9	1568.9	1570.6	1571.1	1572.1	1574.0	1576.4
	137340	1560.9	1565.0	1564.4	1568.0	1566.4	1569.4	1569.2	1571.1	1571.3	1572.6	1574.2	1577.0
	140820	1561.4	1565.6	1565.0	1568.7	1567.1	1570.0	1569.9	1571.6	1571.7	1573.3	1574.5	1577.8
	141850	1561.6	1565.8	1565.1	1568.8	1567.3	1570.1	1570.1	1571.8	1571.8	1573.5	1574.7	1578.0
BROOK'S ADD.	142850	1561.8	1565.9	1565.2	1568.9	1567.3	1570.2	1570.1	1571.9	1571.9	1573.5	1574.7	1578.1
	143630	1561.9	1566.0	1565.3	1569.1	1567.3	1570.2	1570.2	1571.9	1571.9	1573.6	1574.8	1578.2
	144800	1562.1	1566.2	1565.4	1569.4	1567.5	1570.4	1570.3	1572.1	1572.0	1573.8	1574.9	1578.5
	146530	1562.3	1566.5	1565.6	1569.7	1567.6	1570.7	1570.4	1572.4	1572.2	1574.3	1575.2	1579.1
	147100	1562.4	1566.6	1565.7	1569.8	1567.7	1570.7	1570.4	1572.5	1572.3	1574.3	1575.2	1579.2
	147600	1562.5	1566.6	1565.7	1569.9	1567.7	1570.8	1570.5	1572.6	1572.3	1574.4	1575.3	1579.4
	148040	1562.5	1566.7	1565.8	1569.9	1567.8	1570.9	1570.5	1572.7	1572.4	1574.6	1575.3	1579.6
	149540	1563.0	1567.2	1566.3	1570.2	1568.3	1571.5	1571.0	1573.3	1572.9	1575.3	1575.9	1580.3
	150450	1563.2	1567.3	1566.6	1570.3	1568.6	1571.7	1571.2	1573.6	1573.2	1575.5	1576.1	1580.6
	151230	1563.3	1567.4	1566.7	1570.4	1568.7	1571.8	1571.4	1573.7	1573.4	1575.7	1576.5	1580.8
BR AT BURL.	151264	1563.3	1567.4	1566.7	1570.4	1568.7	1571.8	1571.4	1573.6	1573.4	1575.5	1576.5	1580.9
	151265	1563.3	1567.4	1566.7	1570.4	1568.7	1571.8	1571.4	1573.6	1573.4	1575.3	1576.4	1580.9
JOHNSON'S ADD.	151295	1563.3	1567.5	1566.7	1570.4	1568.7	1571.8	1571.4	1573.6	1573.4	1575.5	1576.5	1580.9
(BURLINGTON)	151296	1563.3	1567.5	1566.7	1570.4	1568.7	1571.8	1571.4	1573.9	1573.5	1576.5	1577.0	1580.9
	151350	1563.4	1567.5	1566.7	1570.5	1568.7	1571.9	1571.4	1574.4	1573.6	1576.8	1577.2	1580.9
	151470	1563.4	1567.5	1566.7	1570.5	1568.8	1572.0	1571.5	1574.5	1573.7	1577.0	1577.3	1581.0
	152800	1563.6	1567.7	1566.9	1570.6	1568.9	1572.3	1571.7	1574.6	1574.0	1577.7	1577.7	1581.4
	154250	1563.9	1567.8	1567.1	1570.7	1569.1	1572.5	1571.8	1574.8	1574.1	1577.8	1577.8	1581.6
DES LACS RIVER		Q= 785CFS	Q=1940	1700	Q=3330	2500	Q=6150	4250	Q= 9400	6600	Q=14000	11000	32000
	155475	1564.0	1567.9	1567.3	1570.9	1569.3	1572.7	1572.0	1575.0	1574.2	1578.0	1577.9	1581.8
	161475	1564.1	1568.1	1567.5	1571.1	1569.5	1573.0	1572.1	1575.2	1574.4	1578.2	1578.0	1582.0
	164425	1564.2	1568.2	1567.6	1571.1	1569.5	1573.0	1572.2	1575.3	1574.4	1578.2	1578.1	1582.1
	166825	1564.4	1568.2	1567.7	1571.2	1569.6	1573.1	1572.2	1575.3	1574.5	1578.3	1578.1	1582.2
	168675	1564.6	1568.3	1567.8	1571.2	1569.6	1573.2	1572.3	1575.4	1574.5	1578.3	1578.1	1582.3
	170675	1564.9	1568.3	1567.8	1571.2	1569.6	1573.2	1572.3	1575.4	1574.5	1578.4	1578.1	1582.3
	176075	1565.7	1568.4	1568.0	1571.3	1569.7	1573.2	1572.3	1575.4	1574.5	1578.4	1578.2	1582.5
	1	1566.0	1568.8	1568.2	1571.3	1569.9	1573.2	1572.3	1575.5	1574.5	1578.4	1578.2	1582.5
	2	1566.2	1568.9	1568.5	1571.4	1570.0	1573.3	1572.3	1575.6	1574.6	1578.5	1578.2	1582.6
	3	1566.3	1569.0	1568.5	1571.4	1570.1	1573.3	1572.3	1575.6	1574.6	1578.5	1578.2	1582.6
	4	1566.5	1569.1	1568.6	1571.4	1570.1	1573.3	1572.3	1575.6	1574.6	1578.5	1578.3	1582.6

TABLE A-34 (continued, page 14 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL	5-YR CWSEL		10-YR CWSEL		25-YR CWSEL		50-YR CWSEL		100-YR CWSEL		500-YR CWSEL
		WITH & WITHOUT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITH PROJECT
	5	1566.7	1569.3	1568.9	1571.6	1570.3	1573.4	1572.4	1575.6	1574.6	1578.5	1578.3	1582.7
	6	1567.2	1570.2	1569.7	1571.9	1571.0	1573.6	1572.7	1575.8	1574.7	1578.6	1578.3	1582.8
	7	1567.9	1571.0	1570.6	1572.4	1571.7	1574.0	1573.1	1575.9	1574.9	1578.7	1578.4	1582.9
	8	1568.1	1571.3	1570.9	1572.7	1571.9	1574.2	1573.3	1576.1	1575.1	1578.8	1578.4	1583.0
	9	1568.3	1571.6	1571.1	1573.0	1572.2	1574.5	1573.6	1576.3	1575.2	1578.9	1578.5	1583.0
	10	1568.4	1571.6	1571.2	1573.0	1572.3	1574.6	1573.6	1576.3	1575.3	1578.9	1578.5	1583.1
	11	1568.5	1571.8	1571.4	1573.1	1572.4	1574.7	1573.8	1576.4	1575.3	1578.9	1578.6	1583.2
	12	1568.6	1571.9	1571.5	1573.3	1572.5	1574.8	1573.9	1576.5	1575.4	1579.0	1578.6	1583.2
	13	1568.6	1571.9	1571.5	1573.3	1572.6	1574.9	1573.9	1576.5	1575.5	1579.0	1578.6	1583.2
	14.10	1568.8	1572.1	1571.7	1573.5	1572.7	1575.1	1574.1	1576.8	1575.7	1579.2	1578.8	1583.5
HARRINGTON BR	14.20	1568.8	1572.0	1571.7	1573.5	1572.7	1575.1	1574.1	1576.8	1575.7	1579.2	1578.8	1583.5
	14.30	1568.8	1572.1	1571.7	1573.5	1572.7	1575.3	1574.1	1576.8	1575.8	1579.3	1578.8	1583.6
	14.40	1568.8	1572.1	1571.7	1573.6	1572.8	1575.3	1574.3	1576.8	1575.8	1579.3	1578.8	1583.6
	15	1568.8	1572.1	1571.7	1573.6	1572.8	1575.4	1574.3	1576.9	1575.8	1579.3	1578.8	1583.6
	16	1569.0	1572.3	1571.9	1573.7	1572.9	1575.4	1574.4	1576.9	1575.9	1579.4	1578.9	1583.7
	17	1569.1	1572.4	1572.1	1573.8	1573.1	1575.6	1574.5	1577.0	1576.0	1579.4	1578.9	1583.8
	18	1569.4	1572.8	1572.4	1574.2	1573.5	1575.9	1574.9	1577.3	1576.3	1579.6	1579.0	1583.9
	19	1569.5	1572.9	1572.5	1574.4	1573.6	1576.1	1575.1	1577.4	1576.4	1579.6	1579.1	1584.0
	20	1569.7	1573.1	1572.7	1574.5	1573.8	1576.1	1575.2	1577.5	1576.5	1579.7	1579.1	1584.0
	21	1569.9	1573.2	1572.8	1574.6	1573.9	1576.2	1575.3	1577.6	1576.6	1579.8	1579.2	1584.1
	22	1570.3	1573.4	1573.0	1574.8	1574.0	1576.4	1575.4	1577.7	1576.7	1579.9	1579.3	1584.2
	23	1570.4	1573.6	1573.2	1575.0	1574.2	1576.6	1575.6	1577.9	1576.8	1580.0	1579.4	1584.3
	24.10	1570.5	1573.6	1573.3	1575.0	1574.3	1576.6	1575.6	1577.9	1576.9	1580.0	1579.4	1584.4
BAKER'S BR	24.20	1570.5	1573.6	1573.3	1575.0	1574.3	1576.6	1575.7	1577.9	1576.9	1580.0	1579.4	1584.4
	24.30	1570.5	1573.6	1573.3	1575.2	1574.3	1576.8	1576.0	1578.0	1577.0	1580.1	1579.5	1584.5
	24.40	1570.5	1573.7	1573.3	1575.3	1574.4	1576.8	1576.0	1578.0	1577.0	1580.1	1579.5	1584.5
	25	1570.8	1574.0	1573.6	1575.5	1574.6	1576.9	1576.1	1578.2	1577.1	1580.2	1579.6	1584.6
	26.10	1571.1	1574.4	1574.0	1576.0	1575.2	1577.3	1576.5	1578.4	1577.5	1580.3	1579.7	1584.7
DAM 96	26.20	1571.1	1574.5	1574.0	1576.0	1575.2	1577.3	1576.5	1578.5	1577.5	1580.4	1579.7	1584.7
	26.30	1577.9	1578.4	1578.3	1578.8	1578.5	1579.5	1579.0	1580.2	1579.5	1581.1	1580.6	1584.9
	26.40	1577.9	1578.3	1578.3	1578.8	1578.5	1579.4	1579.0	1580.1	1579.5	1581.1	1580.6	1584.9
	27	1577.9	1578.4	1578.3	1578.9	1578.6	1579.8	1579.3	1580.6	1579.9	1581.7	1581.1	1585.4
	28	1577.9	1578.4	1578.4	1579.0	1578.7	1579.9	1579.3	1580.7	1580.0	1581.8	1581.2	1585.6
	29	1577.9	1578.5	1578.4	1579.0	1578.7	1579.9	1579.3	1580.8	1580.0	1581.9	1581.3	1585.8
	30.10	1577.9	1578.5	1578.4	1579.1	1578.7	1580.0	1579.4	1581.0	1580.2	1582.2	1581.5	1586.1
ST. MARY'S BR	30.20	1577.9	1578.5	1578.4	1579.1	1578.7	1580.1	1579.4	1581.0	1580.2	1582.2	1581.5	1586.1
	30.30	1577.9	1578.5	1578.4	1579.0	1578.7	1580.2	1579.3	1580.9	1580.3	1582.0	1581.3	1586.3
	30.40	1577.9	1578.5	1578.4	1579.1	1578.8	1580.5	1579.5	1581.5	1580.6	1582.5	1581.9	1586.3
	31	1578.0	1578.6	1578.5	1579.3	1578.9	1580.7	1579.7	1581.8	1580.9	1582.9	1582.2	1586.8
	32	1578.0	1578.7	1578.6	1579.4	1579.0	1580.9	1579.9	1581.9	1581.0	1583.1	1582.4	1587.0
	33	1578.0	1578.8	1578.6	1579.6	1579.1	1581.0	1580.0	1582.1	1681.2	1583.3	1582.6	1587.2
	34	1578.0	1578.8	1578.7	1579.6	1579.2	1581.1	1580.1	1582.3	1581.3	1583.5	1582.7	1587.4
	35	1578.1	1578.9	1578.7	1579.7	1579.2	1581.2	1580.2	1582.4	1581.4	1583.6	1582.9	1587.5
	36	1578.1	1578.9	1578.8	1579.8	1579.3	1581.3	1580.3	1582.5	1581.5	1583.7	1582.9	1587.6
	37.10	1578.1	1579.0	1578.9	1579.9	1579.4	1581.4	1580.4	1582.6	1581.6	1583.9	1583.1	1587.8
DAM 87	37.20	1578.1	1579.1	1578.9	1580.0	1579.4	1581.5	1580.5	1582.6	1581.6	1583.9	1583.1	1587.8
	37.30	1579.9	1580.3	1580.2	1580.7	1580.5	1581.8	1581.0	1583.0	1582.0	1584.3	1583.5	1588.0

TABLE A-34 (continued, page 15 of 15)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
BANTRY TO LAKE DARLING DAM

LOCATION	CROSS SEC NO.	2-YR CWSEL	5-YR CWSEL		10-YR CWSEL		25-YR CWSEL		50-YR CWSEL		100-YR CWSEL		500-YR CWSEL
		WITH & WITHOUT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITH PROJECT
	37.40	1579.9	1580.3	1580.2	1580.8	1580.5	1581.8	1581.0	1583.0	1582.0	1584.3	1583.5	1588.0
	38	1579.9	1580.4	1580.3	1580.8	1580.6	1582.0	1581.2	1583.2	1582.1	1584.5	1583.7	1588.3
	39.10	1579.9	1580.4	1580.3	1580.9	1580.6	1582.0	1581.2	1583.2	1582.2	1584.5	1583.7	1588.3
	39.20	1579.9	1580.4	1580.3	1580.9	1580.6	1582.0	1581.2	1583.2	1582.1	1584.5	1583.7	1588.3
	39.30	1579.9	1580.4	1580.3	1580.9	1580.6	1582.0	1581.2	1583.2	1582.2	1584.5	1583.7	1588.3
	40	1579.9	1580.4	1580.3	1581.0	1580.6	1582.3	1581.4	1583.5	1582.4	1584.8	1584.0	1588.5
	41	1579.9	1580.6	1580.4	1581.4	1580.9	1582.9	1581.9	1584.1	1583.0	1585.3	1584.6	1588.8
	42.10	1579.9	1580.7	1580.5	1581.6	1581.1	1583.2	1582.1	1584.5	1583.4	1585.7	1584.9	1589.1
	42.20	1579.9	1580.7	1580.5	1581.6	1581.1	1583.2	1582.1	1584.5	1583.4	1585.7	1584.9	1589.1
	42.30	1579.9	1580.7	1580.5	1581.6	1581.1	1583.2	1582.1	1584.5	1583.4	1585.7	1584.9	1589.2
	43	1580.0	1580.8	1580.6	1581.9	1581.3	1583.7	1582.5	1585.0	1583.9	1586.2	1585.4	1589.6
	44	1580.0	1581.0	1580.8	1582.3	1581.6	1584.2	1583.0	1585.4	1584.4	1586.7	1585.9	1590.1
	45	1580.0	1581.2	1580.9	1582.5	1581.7	1584.5	1583.2	1585.8	1584.7	1587.1	1586.3	1590.5
LAKE DARLING DAM	46	1580.1	1581.3	1581.1	1582.8	1581.9	1584.8	1583.5	1586.1	1584.9	1587.3	1586.6	1590.8

construction of Lake Darling Dam). The model reach lengths between cross sections in the conservation pool area were chosen to reflect valley lengths only.

173. The HEC-2 model from the Lake Darling Dam to Sherwood was calibrated using high water elevations from the 1976 flood, and associated aerial photographs to determine effective flow limits. The peak discharges associated with the 1976 flood profile were approximately 14,500 cfs upstream of the lake, and 8,600 cfs at the outlet of the lake. The final computed water surface elevations for the 1976 flood generally matched the recorded high water elevations to within ±0.5 foot or less. The calibrated channel "n" values ranged from 0.030 within the Lake Darling conservation pool area, to 0.045 for most of the reach upstream of the lake. The calibrated overbank "n" values ranged from 0.030 within the lake, to 0.080 upstream of the lake. Contraction and expansion coefficients of 0.1 and 0.3 were used for relatively uniform reaches, while coefficients of 0.3 and 0.5 were used at more abrupt transitions (such as at bridges).

174. Water surface profiles from the Lake Darling Dam to Sherwood were computed for existing and proposed conditions for the 5-, 2-, 1-, 0.5-, and 0.2-percent chance flood events (i.e., 20-, 50-, 100-, 200-, and 500-year floods, respectively), and for the probable maximum flood (PMF). These computed water surface profiles are shown on plates A-73 through A-80. The corresponding computed water surface elevations are tabulated in table A-35. The proposed (with-project) conditions profiles reflect the proposed modifications to existing reservoir crossings and the proposed levee and channel measures at Renville County Park and the McKinney Cemetery. (The hydraulic design of these project features will be discussed later in this appendix.) The calibrated channel and overbank roughness coefficients were maintained for all of these computed water surface profiles. However, an "n" value of 0.035 was utilized for the proposed channel cutoff at Renville County Park.

175. The computed water surface profiles shown on plates A-73 through A-80 represent a composite of separate profiles which reflect the approximate peak discharges and water surface elevations that would occur within Lake Darling and upstream, for the various flood events considered. Hydrologic analyses indicated that the average reservoir stage on the day of peak inflow to the reservoir would be significantly below the peak reservoir stage reached for all but the larger flood events considered. In addition, the road crossings of the reservoir have relatively small bridge openings, which were expected to cause significant stage increases for the larger flood events. For these reasons, the composite high water profiles were developed from backwater computations through the reservoir for the peak stage at the dam and associated outflow discharge, and from backwater computations from the reservoir upstream for the peak inflow discharge and the associated average reservoir stage on the day of the peak inflow. The highest water surface elevations from these two sets of profiles for each flood event considered was plotted on plates A-73 through A-80, and the associated water surface elevations tabulated in table A-35. A summary of discharges and average reservoir water surface elevations utilized in these analyses is shown below.

TABLE A-35

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
LAKE DARLING DAM TO SHERWOOD

LOCATION	CROSS SEC NO.	20-YR CWSEL		50-YR CWSEL		100-YR CWSEL		200-YR CWSEL		500-YR CWSEL		PMF CWSEL	
		WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT
LAKE DARLING DAM	0	1597.5	1599.0	1601.2	1605.0	1602.9	1605.0	1604.6	1605.0	1606.4	1605.0	1609.0	1609.0
	1	1597.5	1599.0	1601.2	1605.0	1602.9	1605.0	1604.6	1605.0	1606.4	1605.0	1609.0	1609.0
	2	1597.5	1599.0	1601.2	1605.0	1602.9	1605.0	1604.6	1605.0	1606.4	1605.0	1609.0	1609.0
	3	1597.5	1599.0	1601.2	1605.0	1602.9	1605.0	1604.5	1604.9	1606.4	1604.8	1609.0	1609.0
GRAND CROSSING	4	1597.5	1599.0	1601.2	1605.0	1603.1	1605.0	1604.5	1604.9	1606.6	1604.8	1509.3	1610.4
(FAS 3828)	5	1597.5	1599.0	1601.2	1605.0	1603.2	1605.1	1604.8	1605.2	1606.6	1605.6	1609.3	1610.4
	6	1597.5	1599.0	1601.3	1605.0	1603.3	1605.1	1604.8	1605.3	1606.6	1605.7	1609.4	1610.4
	7	1597.5	1599.0	1601.3	1605.0	1603.3	1605.1	1604.8	1605.3	1606.6	1605.7	1609.4	1610.5
	8	1597.5	1599.0	1601.3	1605.0	1603.3	1605.1	1604.8	1605.3	1606.6	1605.7	1609.4	1610.5
	9	1597.5	1599.0	1601.3	1605.0	1603.3	1605.1	1604.8	1605.3	1606.6	1605.7	1609.4	1610.5
	10	1597.5	1599.0	1601.3	1605.0	1603.3	1605.1	1604.9	1605.3	1606.6	1605.7	1609.5	1610.6
	11	1597.5	1599.0	1601.3	1605.0	1603.3	1605.1	1604.9	1605.3	1606.6	1605.7	1609.5	1610.6
	12	1597.5	1599.0	1601.3	1605.0	1603.3	1605.1	1604.9	1605.3	1606.6	1605.7	1609.6	1610.6
	13	1597.5	1599.0	1601.3	1605.0	1603.3	1605.1	1604.9	1605.3	1606.6	1605.7	1609.6	1610.6
	14	1597.5	1599.0	1601.3	1605.0	1603.2	1605.1	1604.8	1605.2	1606.6	1605.6	1609.6	1610.6
SOO LINE RAILROAD	15	1597.5	1599.0	1601.3	1605.0	1603.4	1605.1	1605.4	1605.3	1607.6	1605.7	1610.7	1611.5
	16	1597.5	1599.0	1601.3	1605.0	1603.5	1605.1	1605.5	1605.5	1607.6	1606.1	1610.7	1611.5
	17	1597.5	1599.0	1601.3	1605.0	1603.5	1605.1	1605.5	1605.6	1607.6	1606.4	1610.8	1611.5
	18	1597.5	1599.0	1601.3	1605.0	1603.5	1605.1	1605.5	1605.6	1607.6	1606.4	1610.8	1611.5
	19	1597.5	1599.0	1601.3	1605.0	1603.5	1605.1	1605.5	1605.5	1607.6	1606.2	1610.8	1611.5
STATE HIGHWAY 28	20	1597.5	1599.0	1601.3	1605.0	1603.6	1605.1	1605.8	1605.5	1607.8	1607.9	1611.1	1611.9
	21	1597.6	1599.0	1601.3	1605.1	1603.7	1605.2	1606.0	1605.8	1607.8	1607.9	1611.1	1611.9
	22	1597.6	1599.0	1601.4	1605.1	1603.8	1605.2	1606.1	1605.9	1607.8	1607.9	1611.2	1612.0
	23	1597.6	1599.0	1601.4	1605.1	1603.8	1605.2	1606.1	1605.9	1607.8	1607.9	1611.2	1612.0
	24	1597.6	1599.1	1601.4	1605.1	1603.8	1605.2	1606.1	1605.9	1607.9	1607.9	1611.3	1612.1
	25	1597.6	1599.1	1601.4	1605.1	1603.8	1605.2	1606.1	1605.9	1607.9	1607.9	1611.3	1612.1
	26	1597.6	1599.1	1601.4	1605.1	1603.8	1605.2	1606.1	1605.9	1607.9	1608.0	1611.4	1612.2
	27	1597.6	1599.1	1601.4	1605.1	1603.8	1605.2	1606.1	1605.9	1607.9	1608.0	1611.5	1612.2
	28	1597.6	1599.1	1501.4	1605.1	1603.8	1605.2	1606.1	1605.9	1607.9	1608.0	1611.5	1612.3
	29	1597.6	1599.1	1601.4	1605.1	1603.8	1605.2	1606.2	1606.0	1607.9	1608.0	1611.6	1612.3
	30	1597.6	1599.1	1601.4	1605.1	1603.8	1605.2	1606.2	1606.0	1608.0	1608.1	1611.8	1612.5
	31	1597.7	1599.1	1601.4	1605.1	1603.9	1605.2	1606.2	1606.0	1608.1	1608.2	1611.9	1612.6
	32	1597.7	1599.1	1601.5	1605.1	1603.9	1605.2	1606.3	1606.1	1608.1	1608.2	1612.1	1612.7
	33	1597.7	1599.1	1601.5	1605.1	1603.9	1605.3	1606.3	1606.1	1608.1	1608.3	1612.2	1612.8
	34	1597.8	1599.1	1601.5	1605.1	1603.9	1605.3	1606.3	1606.1	1608.2	1608.3	1612.2	1612.9
DAM 41	35	1597.9	1599.1	1601.5	1605.1	1603.9	1605.3	1606.3	1606.1	1608.2	1608.3	1612.2	1612.9
	36	1598.6	1599.1	1601.5	1605.1	1603.9	1605.3	1606.3	1606.1	1608.2	1608.3	1612.2	1612.9

NOTE: UNDERLINED ELEVATIONS INDICATE CROSSOVER LOCATION OF COMPUTED PROFILES USING DIFFERENT STARTING WATER SURFACE ELEVATIONS AND PEAK DISCHARGES. REFER TO TEXT FOR FURTHER EXPLANATION.

TABLE A-35 (continued, page 2 of 3)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
LAKE DARLING DAM TO SHERWOOD

LOCATION	CROSS SEC NO.	20-YR CWSEL WITHOUT PROJECT	20-YR CWSEL WITH PROJECT	50-YR CWSEL WITHOUT PROJECT	50-YR CWSEL WITH PROJECT	100-YR CWSEL WITHOUT PROJECT	100-YR CWSEL WITH PROJECT	200-YR CWSEL WITHOUT PROJECT	200-YR CWSEL WITH PROJECT	500-YR CWSEL WITHOUT PROJECT	500-YR CWSEL WITH PROJECT	PMF CWSEL WITHOUT PROJECT	PMF CWSEL WITH PROJECT
	37	1598.9	1599.1	1601.5	1605.1	1603.9	1605.3	1606.3	1606.1	1608.2	1608.3	1612.3	1612.9
	38	1599.1	1599.2	1601.5	1605.1	1604.0	1605.3	1606.4	1606.2	1608.3	1608.4	1612.5	1613.1
	39	1599.3	1599.2	1601.6	1605.1	1604.0	1605.3	1606.5	1606.3	1608.4	1608.5	1612.8	1613.4
	40	1599.8	1599.6	1601.8	1605.1	1604.2	1605.4	1606.8	1606.5	1608.7	1608.8	1613.4	1613.9
	41	1600.3	1600.1	1601.9	1605.1	1604.4	1605.4	1607.0	1606.8	1609.0	1609.1	1614.0	1614.4
	42	1600.8	1600.7	1602.6	1605.2	1604.6	1605.6	1607.4	1607.1	1609.4	1609.6	1614.6	1615.0
	43	1601.3	1601.3	1603.2	1605.2	1604.9	1605.6	1607.7	1607.4	1609.7	1609.8	1615.0	1615.4
	44	1601.5	1601.4	1603.4	1605.2	1605.1	1605.7	1607.9	1607.5	1609.9	1610.0	1615.3	1615.6
STATE HIGHWAY 5	45	1601.6	1601.4	1603.5	1605.2	1605.5	1605.7	1607.6	1607.8	1610.3	1610.3	1615.7	1615.9
	46	1601.7	1601.5	1603.8	1605.2	1606.0	1605.7	1608.5	1607.8	1610.3	1610.3	1615.8	1616.0
	47	1601.9	1601.6	1604.1	1605.2	1606.3	1605.8	1608.8	1608.0	1610.4	1610.4	1615.9	1616.2
	48	1602.0	1601.7	1604.2	1605.3	1606.4	1605.8	1608.8	1608.1	1610.5	1610.5	1616.1	1616.3
	49	1602.3	1602.0	1604.4	1605.3	1606.6	1605.9	1609.0	1608.3	1610.7	1610.7	1616.3	1616.5
	50	1602.6	1602.4	1604.7	1605.3	1606.8	1606.2	1609.1	1608.5	1610.8	1610.9	1616.6	1616.8
	51	1603.1	1602.9	1605.1	1605.4	1607.1	1606.6	1609.4	1608.8	1611.1	1611.1	1616.9	1617.1
	54	1603.2	1603.0	1605.2	1605.4	1607.2	1606.6	1609.5	1609.0	1611.2	1611.2	1617.1	1617.2
RENVILLE CO. PARK BRIDGE	55	1603.7	1603.1	1605.3	1605.4	1607.3	1606.8	1609.5	1609.0	1611.3	1611.3	1617.1	1617.3
	56	1603.7	1603.1	1605.3	1605.4	1607.3	1606.8	1609.5	1609.0	1611.3	1611.3	1617.1	1617.3
	57	1603.8	1603.1	1605.3	1605.4	1607.3	1606.9	1609.5	1609.0	1611.3	1611.3	1617.1	1617.4
	60	1603.9	1603.2	1605.5	1605.4	1607.4	1607.0	1609.6	1609.1	1611.4	1611.3	1617.3	1617.4
	61	1604.4	1604.0	1606.0	1606.0	1607.8	1607.7	1609.9	1609.8	1611.7	1611.7	1617.7	1617.8
	62	1604.6	1604.3	1606.3	1606.3	1608.0	1608.0	1610.1	1610.0	1611.9	1611.9	1618.0	1618.1
	63	1604.8	1604.5	1606.5	1606.5	1608.2	1608.2	1610.3	1610.1	1612.1	1612.1	1618.2	1618.3
	64	1604.9	1604.6	1606.6	1606.6	1608.3	1608.2	1610.3	1610.2	1612.2	1612.2	1618.3	1618.4
RENVILLE CO. RD. 9 (FAS 3809)	65	1605.4	1604.6	1606.9	1606.9	1608.4	1608.4	1610.5	1610.4	1612.4	1612.3	1618.6	1618.7
	66	1605.4	1604.7	1606.9	1606.9	1608.4	1608.4	1610.5	1610.4	1612.4	1612.3	1618.6	1618.7
	67	1605.4	1604.8	1606.9	1606.9	1608.5	1608.4	1610.5	1610.4	1612.4	1612.4	1618.7	1618.8
REFUGE BOUNDARY	68	1605.8	1605.3	1607.3	1607.4	1608.9	1608.8	1610.8	1610.7	1612.7	1612.7	1619.0	1619.1
	69	1606.1	1605.7	1607.7	1607.7	1609.2	1609.1	1611.1	1611.0	1613.0	1613.0	1619.3	1619.4
	70	1606.8	1606.5	1608.4	1608.4	1609.8	1609.8	1611.6	1611.5	1613.5	1613.5	1619.8	1619.9
	71	1607.1	1606.9	1608.8	1608.8	1610.2	1610.2	1611.9	1611.9	1613.9	1613.8	1620.2	1620.2
	72	1608.1	1608.0	1609.9	1609.9	1611.3	1611.2	1612.8	1612.8	1614.7	1614.6	1520.8	1620.9
	100	1608.4	1608.3	1610.2	1610.2	1611.6	1611.6	1613.2	1613.1	1615.1	1615.1	1621.3	1621.3
	150	1609.1	1609.1	1611.0	1611.0	1612.4	1612.4	1613.9	1613.9	1615.8	1615.8	1622.1	1622.2
	200	1609.7	1609.7	1611.6	1611.6	1613.0	1613.0	1614.5	1614.4	1616.4	1616.4	1622.7	1622.7
	250	1610.4	1610.4	1612.3	1612.3	1613.8	1613.8	1615.3	1615.3	1617.3	1617.3	1623.8	1623.8
	300	1610.9	1610.9	1612.9	1612.9	1614.4	1614.4	1615.9	1615.9	1618.0	1618.0	1624.6	1624.7

NOTE: UNDERLINED ELEVATIONS INDICATE CROSSOVER LOCATION OF COMPUTED PROFILES USING DIFFERENT STARTING WATER SURFACE ELEVATIONS AND PEAK DISCHARGES. REFER TO TEXT FOR FURTHER EXPLANATION.

TABLE A-35 (continued, page 3 of 3)

COMPUTED WATER SURFACE ELEVATIONS WITH AND WITHOUT LAKE DARLING PROJECT
LAKE DARLING DAM TO SHERWOOD

LOCATION	CROSS SEC NO.	20-YR CWSEL WITHOUT PROJECT	20-YR CWSEL WITH PROJECT	50-YR CWSEL WITHOUT PROJECT	50-YR CWSEL WITH PROJECT	100-YR CWSEL WITHOUT PROJECT	100-YR CWSEL WITH PROJECT	200-YR CWSEL WITHOUT PROJECT	200-YR CWSEL WITH PROJECT	500-YR CWSEL WITHOUT PROJECT	500-YR CWSEL WITH PROJECT	PMF CWSEL WITHOUT PROJECT	PMF CWSEL WITH PROJECT
	350	1611.1	1611.1	1613.1	1613.1	1614.6	1614.6	1616.2	1616.1	1618.3	1618.3	1625.0	1625.0
	400	1611.4	1611.4	1613.5	1613.5	1615.0	1615.0	1616.6	1616.5	1618.7	1618.7	1625.5	1625.5
	450	1612.6	1612.6	1614.5	1614.5	1616.0	1616.0	1617.6	1617.6	1619.7	1619.7	1626.5	1626.5
	498	1612.6	1612.6	1614.5	1614.5	1616.0	1616.0	1617.6	1617.6	1619.7	1619.7	1626.5	1626.5
BARBER BRIDGE	500	1613.2	1613.2	1614.8	1614.8	1616.2	1616.2	1617.8	1617.7	1619.9	1619.9	1626.8	1626.9
(FAS 759)	550	1613.3	1613.3	1614.8	1614.8	1616.3	1616.3	1617.9	1617.8	1620.0	1620.0	1627.0	1627.0
	600	1613.5	1613.5	1615.2	1615.2	1616.6	1616.6	1618.2	1618.2	1620.4	1620.4	1627.3	1627.4
	650	1614.0	1614.0	1615.6	1615.6	1617.1	1617.1	1618.7	1618.6	1620.8	1620.8	1627.8	1627.8
	700	1615.8	1615.8	1617.4	1617.4	1618.8	1618.8	1620.2	1620.1	1622.1	1622.1	1628.8	1628.8
	730	1616.8	1616.8	1618.5	1618.5	1619.8	1619.8	1621.2	1621.2	1623.1	1623.1	1629.7	1629.7
	760	1617.8	1617.8	1619.5	1619.5	1620.8	1620.8	1622.2	1622.2	1624.1	1624.1	1630.6	1630.6
	800	1618.0	1618.0	1619.8	1619.8	1621.1	1621.1	1622.5	1622.5	1624.5	1624.5	1631.0	1631.0
	825	1618.4	1618.4	1620.2	1620.2	1621.5	1621.5	1622.9	1622.9	1624.9	1624.9	1631.5	1631.5
	850	1618.7	1618.7	1620.6	1620.6	1622.0	1622.0	1623.5	1623.5	1625.5	1625.5	1632.2	1632.2
	875	1619.1	1619.1	1621.0	1621.0	1622.5	1622.5	1623.9	1623.9	1626.0	1626.0	1632.8	1632.8
	880	1619.2	1619.2	1621.1	1621.1	1622.6	1622.6	1624.1	1624.1	1626.2	1626.2	1633.1	1633.1
	898	1619.2	1619.2	1621.2	1621.2	1622.6	1622.6	1624.2	1624.2	1626.3	1626.3	1633.2	1633.2
BLUELL BRIDGE	900	1619.3	1619.3	1621.3	1621.3	1622.8	1622.8	1624.3	1624.3	1626.4	1626.4	1633.5	1633.5
	920	1619.3	1619.3	1621.3	1621.3	1622.8	1622.8	1624.3	1624.3	1626.4	1626.4	1633.5	1633.5
	930	1620.0	1620.0	1622.1	1622.1	1623.7	1623.7	1625.3	1625.3	1627.5	1627.5	1634.6	1634.6
	960	1621.3	1621.3	1623.3	1623.3	1624.7	1624.7	1626.2	1626.2	1628.3	1628.3	1635.3	1635.3
	1000	1622.4	1622.4	1624.3	1624.3	1625.7	1625.7	1627.2	1627.2	1629.3	1629.3	1636.2	1636.2
	1050	1622.8	1622.8	1624.8	1624.8	1626.3	1626.3	1627.8	1627.8	1630.0	1630.0	1637.0	1637.0
	1100	1623.3	1623.3	1625.4	1625.4	1627.0	1627.0	1628.5	1628.5	1630.8	1630.8	1637.9	1637.9
	1130	1623.7	1623.7	1625.8	1625.8	1627.4	1627.4	1629.0	1629.0	1631.3	1631.3	1638.6	1638.6
	1160	1624.3	1624.3	1626.4	1626.4	1628.0	1628.0	1629.7	1629.7	1632.0	1632.0	1639.3	1639.3
	1180	1624.6	1624.6	1626.7	1626.7	1628.4	1628.4	1630.1	1630.1	1632.4	1632.4	1639.8	1639.8
	1200	1624.6	1624.6	1626.8	1626.8	1628.4	1628.4	1630.1	1630.1	1632.4	1632.4	1639.8	1639.8
STAFFORD(FAS 728)	1210	1624.7	1624.7	1626.8	1626.8	1628.5	1628.5	1630.2	1630.2	1632.6	1632.6	1640.2	1640.2
	1220	1624.7	1624.7	1626.8	1626.8	1628.5	1628.5	1630.2	1630.2	1632.6	1632.6	1640.2	1640.2
	1250	1624.8	1624.8	1627.1	1627.1	1628.9	1628.9	1630.6	1630.6	1633.0	1633.0	1640.7	1640.7
	1300	1627.0	1627.0	1629.0	1629.0	1630.6	1630.6	1632.2	1632.2	1634.5	1634.5	1642.0	1642.0
	1350	1627.7	1627.7	1629.7	1629.7	1631.3	1631.3	1632.9	1632.9	1635.2	1635.2	1642.8	1642.8
SHERWOOD GAGE	1400	1628.6	1628.6	1630.7	1630.7	1632.4	1632.4	1634.1	1634.1	1636.4	1636.4	1644.1	1644.1
	4444	1628.7	1628.7	1630.9	1630.9	1632.5	1632.5	1634.2	1634.2	1636.6	1636.6	1644.4	1644.4

Flood Frequency	Peak Inflow to Lake Darling (cfs)	Existing Conditions: Average Lake Elevation on Day of Peak Inflow	Existing Conditions: Maximum Lake Elevation at Dam	Existing Conditions: Discharge at Maximum Lake Elev. (cfs)	Proposed Conditions: Ave. Lake Elev. on Day of Peak Inflow	Proposed Conditions: Maximum Lake Elev. at Dam	Proposed Conditions: Discharge at Maximum Lake Elevation (cfs)
5-percent (20-year)	10,500	1594.2	1597.5	4,900	1594.6	1599.0	4,450
2-percent (50-year)	16,900	1597.7	1601.2	9,800	1598.3	1605.0	6,600
1-percent (100-year)	23,200	1600.6	1602.9	16,000	1600.9	1605.0	12,600
0.5-percent (200-year)	30,800	1603.2	1604.6	25,800	1603.8	1605.0	27,700
0.2-percent (500-year)	43,400	1605.8	1606.4	40,300	1605.0	1605.0	42,900
PMF	99,800	1609	1609	99,800	1609	1609	99,800

176. LAKE DARLING DAM TAILWATER RATING CURVE

The tailwater rating curve for Lake Darling Dam was developed using the HEC-2 models for water surface profile computation downstream of the dam. Profiles were computed for a range of discharges from low flows through the PMF, starting at Burlington. Starting water surface elevations at Burlington were obtained from downstream water surface profile computations when possible. For the highest computed profiles, the starting water surface elevations were determined by a profile-convergence method. A reduction of roughness coefficients associated with increasing depths of flooding was utilized for flows greater than 60,000 cfs. However, only a five-percent reduction was used for these very high flows, since the calibrated roughness coefficients for this reach were already quite low. The computed tailwater rating curve for the Lake Darling Dam is shown on plate A-25.

LEVEE AND CHANNEL IMPROVEMENTS

177. GENERAL

Levee and channel improvements are proposed for a number of urban areas downstream of Lake Darling that could be adversely affected by the planned reservoir releases, and at several locations upstream of the dam that would be adversely affected by the increased reservoir stages and associated durations. Levees are also considered an option for protection of the 117 rural residences downstream of the dam that would be affected by the proposed reservoir releases. The description and location of each of these project features is presented in the main portion of this design memorandum. This subsection will generally describe the hydraulic design of these project features, except the downstream rural residence protection, for which the hydraulic design considerations will be addressed in a subsequent design memorandum regarding that subject alone.

178. DOWNSTREAM OF LAKE DARLING

The proposed levee and channel improvements downstream of Lake Darling involve the towns of Velva and Sawyer, and eight housing additions between Minot and Burlington, as indicated on plate 25. All of these urban areas except Velva would be protected against the proposed reservoir release rate of 5,000 cfs at Minot plus 25-year local inflow. At Velva, incremental justification exists for protection up to the post-project 1-percent chance (100-year) flood flow of 14,700 cfs at Velva, as discussed in D.M. No. 4, Velva Improvements, dated November 1982. The design discharges at the other downstream protected urban areas were determined to be that corresponding to the 4-percent chance (25-year) flood event in the Souris River basin, which is approximately the largest flood for which the 5,000 cfs release rate at Minot would not be exceeded. Accordingly, the design discharge for the housing additions between Minot and Burlington was established at 5,000 cfs and the design discharge at Sawyer was set at approximately 5,500 cfs. (See table A-34 for 25-year flood discharges downstream of Lake Darling.)

179. The proposed levee alignments at these urban areas generally follow the alignments of the existing emergency levees. This would minimize the physical disturbance of these areas and the required transport of material for the levees. Thus, levee construction would generally require stabilization, expansion or replacement of the existing emergency levees.

180. Previous hydraulic analyses for the Burlington Dam project indicated that channel modifications (including clearing and snagging) to reduce flood stages and thereby decrease required levee heights were not cost effective. However, these and subsequent studies for the Lake Darling project indicated that channel modifications including a major cutoff would be cost effective at Velva, based primarily on interior flood control considerations (see D.M. No. 4, Velva Improvements). Proposed channel modifications at the other urban protection areas are limited to reaches where the structures to be protected are close to the river, requiring the encroachment of the design levee into the channel. The proposed trapezoidal channel section for these reaches includes side slopes of approximately 1 vertical to 3 horizontal and bottom elevations and channel capacities similar to the existing channel. (This typically involves a 40- to 50-foot channel bottom width.) Riprap or other types of erosion protection are proposed for reaches where the computed average channel velocity is greater than approximately 4 to 5 feet per second at the design discharge. A minimum of 3 feet of freeboard is proposed for all of the downstream urban protection areas except Velva, where the design freeboard varies from 2 feet to over 6 feet (see D.M. No. 4, Velva Improvements, for details). Plan drawings of the proposed levee and channel improvements at Velva, Sawyer and the eight housing additions between Minot and Burlington are shown on plates 26 through 33. The locations of these areas with respect to the computed water surface profiles are also indicated on plates A-53 through A-57 A summary of the proposed levee and channel improvements downstream of Lake Darling is presented in the associated subsection of the main report. Detailed discussions of the proposed interior flood control measures at these protected downstream urban areas are presented later in this appendix.

181. UPSTREAM OF LAKE DARLING

The proposed levee and channel improvements upstream of Lake Darling are located at the Eckert Ranch, McKinney Cemetery and Renville County Park. The relative locations of these areas are shown on plate 7, and plan drawings of the proposed improvements are shown on plates 12, 13 and 14. Without the proposed improvements, these sites would be adversely affected by increased reservoir pool levels and associated durations. Levee and channel improvements were pursued for these sites because fee title acquisition of private land and relocation of the Renville County Park and McKinney Cemetery are considered unacceptable by local interests.

182. The proposed improvements at the Eckert Ranch include levees and a diversion channel. The diversion channel was designed to convey the 1-percent chance peak runoff of approximately 230 cfs from a drainage area of approximately 330 acres. This peak discharge was computed using Horton's method. Because the proposed diversion channel would be dry most of the time, the use of a series of gabion drop structures is considered to be a practical method of reducing velocities within the channel. The infrequency of flows in the channel should also permit the growth of vegetation over the entire channel. For this reason, the maximum permissible velocity for the channel was estimated to be 5 to 6 feet per second. Except near the proposed 2-foot drops, the average computed velocities in the channel at the design discharge were within the permissible range, precluding the need for continuous erosion protection. A minimum of 3 feet of freeboard is proposed for the levee adjacent to the diversion channel. A minimum of 3 feet of freeboard above the design Lake Darling pool elevation of 1605 is proposed for the ring levee southwest of the building site. Higher levee elevations could be utilized if excess material is available from excavation of the proposed diversion channel.

183. The proposed channel cutoff at Renville County Park would have a bank full capacity approximately equal to that of the existing river channel in the area. As indicated in paragraph 172 of this appendix, the existing channel geometry between road crossings upstream of Lake Darling was estimated from channel cross sections at the bridges and the available topographic mapping of the river valley. Based on this information, the preliminary dimensions of the proposed channel cutoff at Renville County Park include a thalweg elevation of approximately 1583 and bottom width of approximately 80 feet. The channel side slopes would be 1 vertical to 3 horizontal. Additional field surveys and hydraulic design analyses will be conducted to verify the proposed cutoff channel design prior to submittal of Design Memorandum No. 9, Reservoir Levees.

184. A modified "Texas" crossing is proposed at Renville County Park in lieu of constructing a bridge over the proposed cutoff channel. The minimum elevation of the crossing would be 1598, or 2 feet above the conservation pool level of Lake Darling. Conduits would be placed through the crossing to allow the passage of low flows. Flow would also be able to pass through the cutoff loop during low-flow periods via controlled openings in the proposed ring levee. Access to the park would be limited to the county road from the east during periods when the Texas crossing is overtopped.

185. The proposed ring levee at Renville County Park would have 3 feet of freeboard above the with-project 1-percent chance (100-year) flood profile, which is shown on plates A-76 through A-80 . Referring to table A-35 this top-of-levee elevation would be approximately 1610. Water surface profile computations indicated that the top-of-levee elevation at the park would need to be raised to approximately elevation 1615 to provide 3 feet of freeboard above the 0.2-percent chance flood, for which the peak discharge is approximately equal to the standard project flood discharge. Riprap would be placed on the proposed levee to protect it against wave action during periods of high reservoir storage levels. Erosion protection would also be provided in the cutoff channel in the vicinity of the Texas crossing, as indicated on plate 12.

RESERVOIR CROSSING RELOCATIONS

186. GENERAL

The proposed increased storage levels and durations within the Lake Darling reservoir would necessitate the modification of the existing railroad and road crossings in the reservoir. These crossings include the Grano crossing, Soo Line Railroad, Highway 28 and Highway 5, for which the locations are shown on plate 7. The proposed modifications would allow these crossings to provide service at least equal to existing conditions. Current state, county and railroad design standards were utilized in the design of the proposed modifications. Wave action was a significant design consideration at these crossings because of the width of the valley (approximately 3000 feet), relatively long fetch distances over which the wind can generate waves and generally windy nature of the project area. Another important design consideration involved the effects of these reservoir crossings on upstream water surface profiles and related real estate acquisition requirements. Modifications to the reservoir crossings were considered which would maintain existing conditions water surface profiles upstream of the Upper Souris Refuge to reduce or avoid the need for the Government to acquire an interest in upstream properties. The proposed modifications to the subject reservoir crossings are shown on plates 8 through 11.

187. WAVE ANALYSES

Wind records from the Minot Airforce Base for the period 1960-1978 were utilized in conjunction with ETL 1110-2-221 to determine design wind speeds for wave forecasting at Lake Darling. Based on these analyses, design wind speeds were determined to be 50 miles per hour from the northerly directions and 40 miles per hour from the southerly directions. Preliminary wave analyses using these design wind speeds indicated transitional water depths for wave forecasting within the reservoir at the design pool elevation of 1605. Because these transitional depths were closer to deepwater conditions than shallow-water conditions, the revised deepwater wave forecasting curves presented in Coastal Engineering Technical Note (CETN) I-7 were used for wave forecasting. Fetch lengths were determined from U.S. Geological Survey quadrangle maps. The wave forecasting parameters and forecasted wave characteristics for each of the reservoir crossings are shown on the next page.

Reservoir Crossing	Design Wind Speed (mph) U/S	Design Wind Speed (mph) D/S	Fetch Length (ft.) U/S	Fetch Length (ft.) D/S	Forecasted Wave Upstream Height (ft.)	Forecasted Wave Upstream Period (sec.)	Forecasted Wave Downstream Height (ft.)	Forecasted Wave Downstream Period (sec.)
Grano	50	40	19,000	26,000	2.8	3.2	2.7	3.3
Soo Line R.R.	50	40	6,000	19,000	1.7	2.2	2.3	3.0
Highway 28	50	40	18,000	6,000	2.8	3.2	1.3	2.0
Highway 5	50	40	10,000	16,000	2.1	2.6	2.2	2.8

188. The proposed minimum roadway elevations for all of the reservoir crossings except the Soo Line Railroad were based on wave runup analyses above the with-project conditions maximum 1-percent chance flood profile, as shown on plate A-78 and tabulated in table A-35 . The proposed minimum elevation for the Soo Line Railroad crossing includes an additional increment to safeguard the stability of the ballast stone. The maximum computed 1-percent chance flood profile was otherwise used as a reference profile because this flood is the largest utilized by the North Dakota State Highway Department for hydraulic design of road crossings. Wave runup for the forecasted design waves was computed using methods presented in Coastal Engineering Technical Report 80-1 and Coastal Engineering Technical Aid 79-1 (two methods were used for comparative purposes). The design wave runup, maximum computed 1-percent chance flood elevation, and proposed minimum roadway elevations for the subject reservoir crossings are as follows:

Reservoir Crossing	Design Wave Runup (ft.)	Maximum Computed With-Project 100-yr Flood Elevation	Proposed Minimum Roadway Elevation
Grano	2	1605	1607
Soo Line R.R.	1.5	1605	1608
Highway 28	2	1605	1607
Highway 5	1.5	1606	1607.5

189. UPSTREAM WATER SURFACE PROFILE CONSIDERATIONS

As previously indicated, consideration was given to reservoir crossing modifications that would maintain existing-conditions water surface profiles upstream of the Upper Souris Refuge. Because the minimum roadway elevations for the reservoir crossings were established by wave action considerations, the only modification to the reservoir crossings that could be made to maintain existing-conditions upstream water surface profiles would be enlargement of the bridge openings. Consideration was given to maintaining open channel

flow conditions under the bridges at the reservoir crossings to minimize head losses and associated upstream backwater effects. The upstream water surface profile reductions achieved by increasing bridge widths were also evaluated. The proposed bridge low chord elevations at each of the reservoir crossings is shown on the respective plan drawing (plates 8 through 11). Because the Highway 5 crossing was found to have the most significant backwater effects upstream, an increase in bridge span of 100 feet is proposed at that crossing. The proposed reservoir crossing modifications would maintain existing-conditions water surface profiles upstream of the refuge to within approximately 0.1 foot, as indicated in table A-35

190. EROSION PROTECTION

Riprap erosion protection would be placed on the slopes of the modified reservoir crossing embankments to prevent erosion by wave action. The proposed riprap layer thicknesses for each of the crossings are shown on plates 8 through 11. Riprap design was based on revetment design procedures presented in the Shore Protection Manual and ETL 1110-2-120. The riprap requirements for the slopes of the road embankments were carried under the bridges, since waves could reach the slopes under the bridges.

INTERIOR FLOOD CONTROL DESIGN

INTERIOR FLOOD CONTROL DESIGN

191. GENERAL

This section of the Appendix defines the interior flood control facilities required in 13 areas located along the Souris River resulting from the proposed construction of levees or a road raise. The areas requiring interior flood control facilities are the Renville County Park, McKinney Cemetery and Eckert's Ranch, located upstream of the Lake Darling dam; two areas west of a proposed road raise west of the Lake Darling Reservoir outlet structure; the residential communities of Johnson's Addition, Brooks' Addition, Talbot's Nursery, Country Club Acres and Robinwood Estates, King's Court and Rostad's Addition and Tierrecito Vallejo, located just upstream from the City of Minot; and the village of Sawyer and the city of Velva located downstream from Minot. The location of these areas along with the drainage area boundaries is shown on Plates A-81, A-82 and A-83.

192. Major interior flood control features consist of gated gravity outlets, permanent and portable stormwater pumping stations, temporary ponding areas, and intercepting storm sewers. Some interior culverts and drainage ditches may also be required to carry the interior runoff to designated ponding areas or gravity outlets. Included in this Appendix is a summary of the preliminary hydrologic and hydraulic analysis used to obtain the recommended size of the major interior flood control facilities in all areas, except at Velva. Details relative to the design of interior flood control features at Velva are presented in Appendix A of Design Memorandum No. 4 - "Velva Improvements." The recommended major interior flood control features are summarized in Tables A-39 and A-40 and shown on Plates 2, 12 through 14 and 26 through 33 in the main report.

193. LOCATION AND LAND USE

A description of each of the 11 levees areas investigated, except the city of Velva, are presented in the following paragraphs.

194. Renville County Park, also known as Moose River Park (shown on Plate 12), serves as a central recreation area for Renville County. Located about 2½ miles upstream from State Highway 5 along the left bank of the river, Renville County Park contains about 90 privately owned seasonal cottages and 5 county owned buildings, including a cafeteria, bar, rollerskating center and auditorium. The park covers about 70 acres and also contains about 7 permanent, year round residents.

195. McKinney Cemetery (shown on Plate 13) is located about one-fourth mile south of State Highway 5 on the west edge of the river valley and contains about 250 graves within a 4.3 acre site.

196. Eckert's Ranch (shown on Plate 14) is located along the left bank of the Souris River/Lake Darling Reservoir a short distance upstream from the reservoir outlet. The ranch covers about 700 acres and contains 18 structures clustered together, including the residence.

197. Johnson's Addition (shown on Plate 26) is located approximately 14.2 river miles upstream of the Broadway Avenue Bridge in Minot, on the left bank of the Souris River. The 73 acres protected by the proposed levee alignment contains approximately 30 acres of low-density suburban residential property and approximately 10 acres of farmland. The remainder of the area consists of wooded low lands and abandoned oxbows of the river. This entire area has been annexed recently by the City of Burlington, North Dakota.

198. Brooks' Addition (shown on Plate 27) is a small unincorporated community located approximately 12.5 river miles upstream of the Broadway Avenue Bridge in MInot, on the left bank of the Souris River. The 49 acres that will be protected by the proposed levee is equally divided between low-density suburban residential property and wooded marshland that surrounds several abandoned oxbows of the river.

199. Talbot's Nursery (shown on Plate 28) is located approximately 11.2 river miles upstream of the Broadway Avenue Bridge in Minot on the right bank of the Souris River. The 11-acre protected area is currently being utilized as a commercial trailer park.

200. The subdivisions of Country Club Acres and Robinwood Estates (shown on Plate 29) are located about 10.4 miles upstream of the Broadway Avenue Bridge in Minot on the left bank of the Souris River. The 110 acre protected area is a low-density residential area.

201. The subdivisions of King's Court and Rostad's Addition (shown on Plate 30) are located about 9.7 river miles upstream of the Broadway Avenue Bridge in Minot on the right bank of the Souris River. The 25 acre protected area is a low-density residential community.

202. Tierrecito Vallejo (shown on Plate 31) is located on the left bank of the Souris River approximately 4.0 river miles upstream of the Broadway Avenue Bridge in Minot. The 32.8 acre protected area is composed of low-density, residential properties.

203. The Village of Sawyer (shown on Plate 32) is located approximately 33 river miles downstream of the Broadway Avenue Bridge in Minot on the right bank of the Souris River. Approximately one-third of the 43 acre protected area is low-density, residential properties. Another one-third of the area contains a small commercial grain elevator and a portion of a farm. The remaining area contains many abandoned camp buildings, open grassland, and a large oxbow.

204. EXISTING STORMWATER DRAINAGE

During recent years, emergency levees have been constructed in many of the study areas prior to a spring flood. Corrugated metal pipe (CMP) culverts have been placed through these existing levees in some areas to convey the runoff to the river. Flap gates are provided on the culverts in several of these protected areas while in other areas the culverts must be sandbagged during high river stages to prevent flooding from the river. The City of Velva is the only community which currently has a storm sewer system to convey runoff directly to the river. Coincidental runoff during high river stages is presently pumped out of the sewers and into the river by temporary portable pumps. Current runoff patterns in each of the 11 areas (except the City of Velva) which are to receive flood protection is further described in the following paragraphs.

205. Renville County Park - Runoff from the 185.5 acre contributing watershed is currently by overland flow all of which discharges directly into the Souris River.

206. McKinney Cemetery - Runoff from the 7.3 acre contributing watershed is currently by overland flow all of which discharges directly into the Souris River. A portion of the cemetery, including approximately 50 graves will be inundated by flood storage up to the reservoir design pool elevation 1605.

207. Eckert's Ranch - Runoff from the 15.8 acre contributing watershed is currently by overland flow all of which discharges directly into the Souris River.

208. Johnson Addition - The existing emergency levee surrounding Johnson's Addition has a contribuing interior drainage area of approximately 960 acres. Most of the runoff in this basin presently collects in a very large abandoned oxbow and the remaining runoff collects in several smaller isolated depressions as shown on Plate A-82 . About 22 acres of the drainage area is separated from the main area by a paved road (Ward County Route 10) and runoff from half of this area collects in a low area adjacent to the river. The other 11 acres drains under Ward County Route 10 through two 36-inch concrete culverts into the large abandoned oxbow. Approximately 806 acres of the existing drainage basin are located on the bluff area southwest of U.S. Highway 52 and the runoff from this area passes through several culverts under the highway and then through a 48-inch culvert under the Soo Line Railroad tracks. From this point, natural drainage paths convey the runoff to the large abandoned oxbow. Of the remaining 132 acres, approximately 100 acres drain by overland flow to this oxbow and runoff from the rest of the area collects in several smaller depressions. The runoff which is ponded in the large abandoned oxbow is discharged through a 15-inch corrugated metal pipe (CMP). At this point, the runoff is conveyed by a natural drainage ditch to another 15-inch CMP through the emergency levee and into the river. There is a flap gate on this pipe to prevent water from entering the protected area during high river stages. Temporary portable pumps are currently used to prevent damage from high water in the large oxbow and the several smaller

depressions during prolonged periods of high river stages and coincidental rainfall. The proposed levee as shown on Plate will be aligned directly across the large abandoned oxbow and will eliminate a major portion of the existing contributing drainage area from the protected area. With the proposed levee alignment the contribuing drainage area will be reduced to 102.6 acres. The remaining area will drain directly to the Souris River.

209. Brooks' Addition - About one-third of the existing 325-acre drainage area drains into a series of three interconnected abandoned river loops lying in the central and southern portion of the protected area. The remainder of the drainage area lies up in the plateau area and bluffs as shown on Plates 27 and A-82 . Runoff from this area passes through a 36-inch CMP under Ward County Route 15 and then into the abandoned river loop closest to the river. All of the water which collects in this loop is transported through the existing emergency levee by an 18-inch CMP during low river stages. At high river stages, this outlet is plugged and the ponded water is removed by temporary portable pumps which discharge into the Souris River.

210. Talbot's Nursery - About half of the 38.3 acre drainage area drains to a large abandoned oxbow at the downstream portion of the protected area. The remaining runoff collects in a smaller oxbow located at the upstream portion of the area as shown on Plate 28 . Presently, there are two 18-inch CMP culverts under the roadway which convey runoff towards the large downstream abandoned oxbow. There are no permanent, existing facilities for transporting ponded water through or over the levee after collecting in the oxbows. During low flow periods, the oxbows are drained to the river by horizontal seepage through intermittent sand layers which underlie much of the area. The estimated seepage from the oxbow is 39 gpm per foot of head. During flood periods, temporary portable pumps are used to keep the water surface in the oxbows at an acceptable elevation.

211. Country Club Acres - About one-half of the runoff in a 132-acre basin (as shown on Plates 29 and A-82) presently collects in the large abandoned oxbow in the center of the area. Another twenty percent is intercepted by a portion of another old oxbow, in the northeast portion of the area. The remaining runoff collects in several isolated depressions adjacent to the emergency levee. The runoff which collects in the eastern half of the large abandoned oxbow in the center of the area flows through an existing 30-inch CMP culvert under Thomas Drive and into the western half of the oxbow. Ponded water is then conveyed under Parkwood Drive at the southern section of the oxbow by a 24-inch CMP culvert and then during low river stages through the emergency levee into the Souris River by a second 24-inch CMP culvert. A portion of another abandoned oxbow at the northern section of the area collects runoff from about 24 acres. Water in this depression currently drains north into the Minot Country Club through a 30-inch CMP culvert under Old Ward County Route 15. Runoff from the remaining area is collected in numerous low points along the levee.

212. King's Court - Runoff from about 8.6 acres in the northeastern portion of the drainage basin is conveyed by overland flow and roadside ditches to the east end of Delnor Drive. From there it is discharged through the existing emergency levee by means of an 18-inch corrugated metal pipe (CMP) with a flap-gate. About 0.7 acres also in the northeast portion is drained by a 10-inch CMP through the levee. During periods of high river flows, the 10-inch culvert is temporarily closed by means of sand bags. Runoff from the 11.2 acres in the western and central portion of King's Court presently collects in a natural low spot in the center of the area. The water which is ponded in this low spot eventually drains to the river by means of seepage during low river stages. However, if a sufficient amount of rainfall occurs, the ponded water will overflow into the southeastern portion of the area and combine with the runoff from the remaining 6.3 acres of the drainage basin and drain to the river through a 24-inch CMP with a flap gate. During high river stages, all of the runoff collects in several natural low areas and this combined with the seepage inflow is pumped over the levee using temporary portable pumps.

213. Tierrecito Vallejo - The entire 32.8 acre drainage basin lies entirely within the protected area. The runoff travels overland into small roadside ditches and through culverts under the road to several natural low areas adjacent to the existing emergency levee. About 10 acres drain to an 7-inch steel pipe in the northeast portion of the area, while most of the remaining acreage drains to an 18-inch CMP culvert with a sluice gate. However, both of these culverts have been heavily damaged during the recent emergency levee construction and in their current condition are unreliable for draining the area. During flood periods, the runoff which collects at these two outlets and at two other low areas is pumped over the levee into the Souris River using portable pumps.

214. Sawyer - Runoff from the 21.7 acres south of the Soo Line Railroad is conveyed through a series of existing culverts along the western side of Dakota Avenue to a concrete culvert under the railroad tracks. At this point, it combines with the runoff from the 30.3 acres north of the tracks and west of Dakota Avenue and collects in a large abandoned oxbow in the center of the protected area. The remaining 20 percent of the drainage area drains directly into a shallow depression on the east side of Dakota Avenue as shown on Plate 32. During low river stages, ponded water in the shallow depression drains into the large oxbow by seepage under the road and the water in the large abandoned oxbow is drained by seepage into the Souris River.

215. PRESENT SANITARY SEWER SYSTEM

There are sanitary sewers in all of the protected areas, except Brooks' Addition, Talbot's Nursery, Tierrecito Vallejo, and the three areas upstream of the Lake Darling reservoir outlet structure. A septic system is available in each of these remaining areas, except for the cemetery. Sewage from King's Court and Rostad's Addition, Country Club Acres and Robinwood Estates, and Johnson's Addition is conveyed by

forcemain to sewage treatment lagoons in Burlington, North Dakota. The forcemain leading from Country Club Acres is located under the proposed levee. Also in Country Club Acres, a water supply line crosses the proposed levee alignment adjacent to the sanitary forcemain. In the Village of Sawyer, there is also a forcemain under the levee which conveys sewage to the Sawyer treatment lagoon. In Velva, sewage is conveyed to a lift station located near the existing emergency levee in the northeast portion of the city. This lift station pumps the sewage under the Souris River to the city's sewage treatment lagoons on the north side of the river.

216. PROPOSED INTERIOR FLOOD CONTROL FACILITIES

Renville County Park - The recommended interior drainage facilities for Renville County Park will consist of a 10-foot stop-log closure at the upstream end of the portion of the Souris River to be bypassed with the construction of the proposed cutoff channel (and to be used as a temporary ponding area during blocked gravity conditions), a 90-inch RCP gated gravity outlet at the downstream end, and a 3000 gpm permanent stormwater pumping station. The proposed plan is shown on Plate 12 . The 10-foot stoplog closure is recommended to permit fishing above the park. During non-flood periods, runoff from the 185.5 acre drainage basin will flow overland to the temporary ponding area, thence through the 90-inch outlet into the main Souris River Channel. During periods of blocked gravity drainage, runoff into the ponding area will, if necessary, be pumped over the levee into the gatewell on the 90-inch outlet.

217. McKinney Cemetery - The recommended interior flood control facilities for the McKinney Cemetery will consist of a 24-inch RCP gated gravity outlet and facilities for installing a 3000 gpm portable pump. The proposed plan is shown on Plate 13 . During non-flood periods, runoff from the 7.3 acre drainage basin will flow overland to and through the gravity outlet into the river. During periods of blocked gravity flow, runoff will be pumped over the levee into the river.

218. Eckert's Ranch - The recommended interior flood control facilities for the Eckert's Ranch area will consist of a 36-inch RCP gated gravity outlet and facilities for installing a 1300 gpm portable pump. The proposed plan is shown on Plate 14 . During non-flood periods, runoff from the 15.8 acre drainage basin will flow overland to and through the gravity outlet. Druing periods of blocked gravity flow, runoff will be pumped over the levee into the river.

219. Area West of Roadraise - The recommended interior flood control facilities for the areas located west of the proposed road raise west of the Lake Darling outlet structure will consist of one 36-inch RCP gated gravity outlet upstream of the outlet structure and one 24-inch RCP gated gravity outlet downstream of Lake Darling. The proposed plan

is shown on Plate 2 . During non-flood periods, runoff from the 110.2 and 46.8 acre drainage basins will flow overland to and through the gravity outlets. During periods of blocked gravity flow, runoff will pond west of the roadway adjacent to each outlet.

220. Johnson Addition - The project plan provides for a gated-gravity outlet and a permanent stormwater pumping station as shown on Plate 26. All of the interior drainage will be routed to the ponding area formed by the large abandoned oxbow in the south portion of the protected area. Drainage of the small isolated depressions will be facilitated by a series of culverts and drainage ditches. During non-flood periods, the runoff will drain from the protected area through a 24-inch reinforced concrete pipe (RCP) gated gravity outlet through the levee. At this point the runoff will be conveyed by a drainage ditch east along the levee into the Souris River. During blocked gravity flow conditions, the seepage and runoff which collects in the ponding area will be pumped into the gravity outlet gatewell by a 3000 gallon per minute (gpm) pumping station.

221. Brooks' Addition - The recommended permanent interior drainage plan for Brooks' Addition consists of a 36-inch RCP gated-gravity outlet and a 3000 gpm permanent pumping station. Several low areas adjacent to the levee will be filled and a series of drainage ditches and culverts will convey the runoff to the ponding area formed by the abandoned oxbows as shown on Plate 27 . During non-flood periods, the runoff which collects in the ponding area will be drained by the gravity outlet and discharged through the levee into the Souris River. During blocked-gravity flow conditions, the seepage and runoff which collects in the ponding area will be pumped over the levee and into the gravity outlet gatewell.

222. Talbot's Nursery - The recommended interior drainage plan for Talbot's Nursery includes a 24-inch RCP gated-gravity outlet and a 3000 gpm permanent stormwater pumping station. Five hundred fifty-three (553) feet of culvert and 565 feet of drainage ditches will be provided to convey runoff from the small abandoned upstream oxbow to the large downstream oxbow. Runoff from the entire drainage basin will collect in the large oxbow which will be utilized as a ponding area for both the gravity outlet and pumping station. During non-flood periods, the water will be discharged through the gravity outlet to the Souris River. During blocked gravity flow conditions, the seepage and runoff which is ponded will be pumped over the levee and into the gravity outlet gatewell.

223. Country Club Acres and Robinwood Estates - The recommended permanent interior drainage plan for Country Club Acres and Robinwood Estates consists of a 24-inch RCP gated-gravity outlet and a 3000 gpm stormwater pumping station. Runoff from the entire area will be collected and brought to the large abandoned oxbow in the center of the area which will be utilized as a ponding area. Emergency construction measures taken during the 1976 spring floods have diverted the bluff

area drainage away from the protected area. This bluff runoff is conveyed along the eastern edge of Robinwood Estates and discharges into the Souris River downstream of the protected area. The old small oxbow in the northeastern portion of the area will be connected to the ponding area by means of a RCP culvert. The CMP culvert which currently drains this small oxbow, north under Old Ward County Route 15 will be plugged with concrete. Numerous low areas adjacent to the levee will be filled in and/or drained by drainage ditches and culverts, as shown on Plate 29 . During non-flood periods, the runoff which collects in the ponding area in the center of the area will be drained by the gravity outlet and discharged through the levee into the Souris River. During blocked-gravity flow conditions, the seepage and runoff which collects in the pond will be pumped over the levee and into the gravity outlet gatewell.

224. King's Court and Rostad's Addition - The recommended interior drainage facilities for King's Court and Rostad's Addition consist of 1,565 feet of stormsewer, a 30-inch RCP gated-gravity outlet and a 3000 gpm permanent stormwater pumping station. The proposed plan is shown on Plate 30 . Several low areas will be filled and drained towards the interceptor or the ponding area. Runoff from the northeast portion of the drainage area will be intercepted by the storm sewer carried to the gravity outlet. Runoff from the remaining area will travel by overland flow to the ponding area and then through the gravity outlet into the Souris River. During blocked-gravity flow conditions, the runoff and seepage which collects in the pond will be pumped over the levee and into the gravity outlet gatewell.

225. Tierrecito Vallejo - The recommended interior drainage facilities for Tierrecito Vallejo consist of two 24-inch RCP gated-gravity outlets and a 3000 gpm permanent stormwater pumping station. The proposed plan is shown on Plate 31 . Three different low areas adjacent to the river will be filled and made to drain towards gravity outlet No. 1. To reduce the size of both gravity outlet and pumping station, a ponding area will be excavated. During non-flood periods, runoff from the 10 acres in the northern portion of the drainage basin will drain through outlet No. 2 and into the Souris River. Runoff from the remaining 22.8 acres will travel by overland flow to the ponding area and then through outlet No. 1 into the river. During periods of blocked-gravity flow, runoff from the 22.8 acre drainage area will be pumped over the levee and into the outlet No. 1 gatewell. Runoff from the 10-acre drainage basin will be ponded upstream of outlet No. 2 and released when the pond stage exceeds the river stage by six inches or more.

226. Sawyer - The recommended permanent interior drainage scheme for the Village of Sawyer consists of a 24-inch RCP gated-gravity outlet. The drainage from several isolated depressions will be conveyed to the ponding area by 785 feet of drainage ditches and a single RCP culvert located under Dakota Avenue. The proposed plan is shown on Plate 32 A permanent pumping station will not be required at Sawyer because of the large natural ponding area. However, a portion of Dakota Avenue will be raised to about elevation 1520.5 in order to permit the road to be used during prolonged periods of blocked-gravity flow.

227. ALTERATIONS AND RELOCATIONS

In both Sawyer and Country Club Acres, there is a sanitary forcemain located under the proposed levee. At each location, the forcemain will be raised to within five feet of the top of the levee. A gate valve will be placed in the sewage line to provide for an emergency closure of the forcemain. An 8-inch water main is located under the line of protection in Country Club Acres. Provisions will be made to raise this line to within five feet of the top of the levee and a gate valve will be placed in the line. All gate valves will be located in a concrete manhole on the riverside of the levee, five feet from the crest. At each change in alignment under the levee, a moveable joint will be provided to account for any differential settlement of the levee. Approximately 200 feet of gravel road will be raised about one foot in Sawyer in order to keep the road surface on Dakota Avenue above the water surface of the ponding area during prolonged periods of blocked-gravity flow.

228. PONDING AREAS

The location of the proposed ponding areas are presented on Plate 12 and Plate 14 of the main report. Elevation-area-capacity curves obtained from available aerial and strip topographic maps for each location are presented on Plates A-84 through A-88 . These curves were used in the interior flood control analysis to determine the amount of pondage available and subsequently to determine the required size of outlet and capacity of pumping station.

229. DAMAGE-ELEVATION DATA

Damage surveys were conducted to determine the damage-elevation relationships for each of the protected areas. Ponding stages were determined corresponding to Damage Stages "A", "B", "C", and "D" as described in EM 1110-2-1410. The stage C and stage D ponding levels selected for each area are presented in Table A-39 .

230. STAGE-DURATION-DISCHARGE DATA

Stage-duration-discharge curves for the Souris River at each interior flood control outlet structure downstream of the Lake Darling dam are presented on Plates A-99 , A-100, and A-101. Stage-duration relationships for the Souris River at each outlet structure upstream of the dam can be obtained from the elevation-duration relatio ..ips presented on Plate A-45 .

231. The stage-duration-discharge curves for the 6 protected areas located along the Souris River between the Lake Darling dam and the City of Minot were developed based on a backwater analysis (described on page A-75), using streamflow data obtained from the USGS gaging station above Minot modified to reflect the proposed operating plan and assuming the proposed levee, channel improvements and dam raise

have been completed. All six of the areas are located within an eleven mile reach of the Souris River above Minot and the USGS gaging station is located about 7.5 river miles upstream of the Broadway Avenue bridge in Minot. During the period from 1939 through 1975, streamflow at the USGS gage has varied from 0 to about 5750 cfs and the average flow was about 141 cfs. With the proposed operating plan, the maximum flow in the river will be about 5000 cfs at the gage.

232. Since streamflow records are not available at Sawyer or Velva, the stage-duration-discharge curves for these areas were developed based on streamflow records obtained from the USGS gaging stations located above Minot and at Verendrye, about 80 river miles downstream from Minot. Before the streamflows at Sawyer and Velva could be estimated, it was necessary to modify the Verendrye streamflows to reflect the controlled releases from the dam. The flood retentions above 5000 cfs at Minot were routed to Verendrye using the Progressive Average Lag Method presented in EM 1110-2-1408, assuming a five day travel time. The results of these routings were then used to modify the recorded Verendrye streamflows for the years 1969 and 1975, the only years since 1939 during which a flow greater than 5000 cfs was recorded at Minot.

233. The difference between the primary contribuing Souris River drainage areas of Sawyer (4,230 square miles) and Velva (4,330 square miles) is less than 2.4 percent. It was assumed, therefore, that at a point midway between Sawyer and Velva the calculated streamflow would be applicable to both communities. The streamflow at this "midpoint" was computed by taking the modified Minot streamflow for a given date, subtracting this from the modified Verendrye streamflow five days later, and multiplying this difference by the ratio of the drainage areas. This value is then added to the original Minot streamflow to determine the streamflow at the Sawyer/Velva "midpoint" three days later. The three-day travel time from Minot to the "midpoint" was estimated by proportioning the river miles from Minot to the "midpoint" and Minot to Verendrye.

234. HYPOTHETICAL PRECIPITATION DATA

Hypothetical rainfall events were used to establish the required sizes of all interior flood control facilities. The 1-, 2-, 3-, 6-, 12-, 24-, 48- and 96-hour duration rainfall depths for the 100-, 50-, 20-, 10-, 2-, and 1-percent rainfall events in the Minot/Velva areas were obtained from the U.S. Weather Bureau Technical Report Nos. 40 and 49. Standard project storm rainfall data was obtained from EM 1110-2-1411. Rainfall depth-duration-frequency relations were determined in accordance with EM 1110-2-1410 and are presented on Plates A-90 and A-91 . Hypothetical storms were developed and rainfall excess calculated for the 100-, 50-, 20-, 10-, 2-, 1-percent and standard project storms as shown on Plates A-92 through A-98 .

235. RUNOFF HYDROGRAPHS

Runoff hydrographs have been obtained for each watershed by application of the hypothetical hyetographs to unit hydrographs obtained for each area. Unit hydrographs were computed using summation hydrographs (S curves) and lag relations for each area. Summation hydrographs were computed from the Horton overland flow equation given in TM 5-820-1 as follows:

$$q = r_e \tanh^2(0.922t(r_e/nL)^{0.50}S^{0.25})$$

Where:

q = rate of overland flow in cfs per acre

r_e = rate of rainfall excess in inches per hour

tanh = hyperbolic tangent function

t = time in minutes after start of rainfall

n = retardance coefficient

L = effective length of drainage path in feet

S = effective slope of drainage path in feet per foot

236. The 30-minute unit hydrographs developed for each area are presented in Table A-37 and the parameters used to obtain the unit hydrographs are presented in Table A-36. Table S-38 presents the 100- and 1-percent and standard project storm runoff hydrographs for each area. Retardance coefficients used to develop the unit hydrographs were selected based on the weighted average land use and type of ground cover in the area.

237. DESIGN CRITERIA

A summary of the recommended requirements and design data used for selecting the size of proposed gravity outlets and pumping stations are presented in Tables A-39 and A-40 , respectively. The estimated required length of 24-inch RCP stormwater interceptor in the King's Court and Rostad's Addition is about 1565 feet as shown on Plate 30 of the main report. Contributing interior drainage areas, potential gravity outlet locations, pumping station sites, stormsewer locations and temporary ponding areas were obtained from field reconnaissance and/or topographic and drainage maps.

238. Gravity Design

The design of gravity outlets (summarized in Table A-39) were sized to pass the 1-percent storm runoff at or below the stage C pond level and the standard project storm runoff at or below the stage D pond level. The selection of the recommended invert elevations of the gravity outlets was based on local topography, and damage-elevation and stage-duration relationships.

TABLE A-36

UNIT HYDROGRAPH PARAMETERS*

Study Area	Drainage Area in Acres	Length of Drainage Path in Feet	Retardance Coefficient "n"	Average Slope in Ft./Ft.
UPSTREAM OF LAKE DARLING OUTLET STRUCTURE				
Renville County Park	185.5	3,400	0.38	.0441
McKinney Cemetery	7.3	750	0.40	.0467
Eckert's Ranch	15.8	1,300	0.40	.05
WEST OF PROPOSED ROAD RAISE				
Upstream of Outlet Structure	110.2	5,400	0.40	.0389
Downstream of Outlet Structure	46.8	2,400	0.40	.0667
OUTLET STRUCTURE DOWNSTREAM TO MINOT				
Johnson's Addition	102.6	1,280	0.35	.0082
Brooks' Addition	325.0	6,350	0.35	.0283
Talbot's Nursery	38.3	2,050	0.35	.0088
Country Club Acres and Robinwood Estates	132.0	2,500	0.35	.0032
King's Court and Rastad's Addition	26.8	2,010	0.11	.0038
Tierrecito Vallejo				
Subarea A (Outlet No. 1)	22.8	1,650	0.35	.0036
Subarea B (Outlet No. 2)	10.0	1,550	0.35	.0032
SAWYER	65.3	2,425	0.40	.0369
VELVA				
Area A	173.6	4,800	0.28	.0001
Area B	169.8	4,700	0.31	.0383
Area C	802.	15,900	0.40	.0107
Area D	32.5	2,300	0.27	.001
Area E	65.2	4,300	0.25	.003
Area F	53.7	3,100	0.30	.002
Area G	600.	7,125	0.40	.0199

*The rainfall excess (R_e) and hydrograph lag time are 2.0 inches per hour and 30 minutes, respectively, for each area.

TABLE A-37

30-MINUTE UNIT HYDROGRAPHS

Time in Hours	Renville County Park	McKinney Cemetery	Eckert's Ranch	Damsite Roadraise-Upstream	Damsite Roadraise-Downstream	Johnson's Addition	Brooks' Addition	Talbot's Nursery	Country Club Acres	King's Court	Tierrecito Vallejo Subarea A	Tierrecito Vallejo Subarea B	Sawyer	Velva
0.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	See
0.25	22.	3.	5.	8.	9.	15.	19.	4.	6.	5.	2.	1.	9.	Table A-17
0.50	79.	9.	14.	28.	30.	52.	70.	14.	25.	18.	7.	3.	33	Page A-46
0.75	127.	9.	18.	50.	43.	81.	125.	23.	45.	25.	11.	5.	51.	Design
1.00	136.	5.	13.	60.	39.	81.	158.	26.	58.	22.	14.	6.	51.	Memorandum
1.25	117.	2.	7.	61.	28.	64.	167.	24.	63.	16.	13.	6.	41.	No. 4
1.50	89.	1.	4.	55.	17.	29.	158.	19.	61.	10.	12.	5.	29.	
1.75	62.	0.	2.	46.	10.	18.	138.	14.	56.	5.	9.	4.	19.	
2.00	41.		1.	36.	6.	11.	114.	10.	48.	3.	7.	3.	12.	
2.25	26.		0.	27.	3.	6.	90.	7.	39.	2.	5.	2.	7.	
2.50	17.			20.	2.	4.	69.	5.	31.	1.	4.	2.	4.	
2.75	10.			15.	1.	2.	52.	3.	24.	0.	3.	1.	2.	
3.00	6.			10.	0.	1.	39.	2.	19.		2.	1.	1.	
3.25	4.			7.		1.	28.	1.	14.		1.	0.	1.	
3.50	2.			5.		0.	21.	1.	11.		1.		0.	
3.75	1.			4.			15.	0.	8.		0.			
4.00	1.			2.			11.		6.					
4.25	0.			2.			8.		4.					
4.50				1.			6.		3.					
4.75				1.			4.		2.					
5.00				0.			3.		2.					
5.25							2.		1.					
5.50							1.		1.					
5.75							1.		0.					
6.00							1.							
6.25							0.							

TABLE A-38

RUNOFF HYDROGRAPHS

Time in Hours	Renville County Park 1 Percent Event	Renville County Park Standard Project Storm	Renville County Park 100 Percent Event	McKinney Cemetery 1 Percent Event	McKinney Cemetery Standard Project Storm	McKinney Cemetery 100 Percent Event	Eckert's Ranch 1 Percent Event	Eckert's Ranch Standard Project Storm	Eckert's Ranch 100 Percent Event
0.00	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.25	1.	8.	1.	0.	1.	0.	0.	2.	0.
0.50	4.	30.	4.	0.	3.	0.	1.	5.	1.
0.75	7.	53.	7.	1.	4.	1.	1.	8.	1.
1.00	8.	67.	8.	0.	4.	0.	1.	8.	1.
1.25	11.	79.	10.	1.	4.	0.	1.	8.	1.
1.50	15.	93.	12.	1.	5.	1.	2.	10.	1.
1.75	19.	104.	14.	1.	5.	1.	2.	10.	1.
2.00	21.	106.	14.	1.	4.	1.	2.	9.	1.
2.25	23.	108.	15.	1.	4.	1.	2.	9.	1.
2.50	26.	118.	16.	1.	6.	1.	3.	11.	1.
2.75	28.	127.	17.	1.	6.	1.	3.	12.	2.
3.00	29.	127.	16.	1.	5.	1.	3.	11.	1.
3.25	30.	130.	16.	1.	5.	1.	3.	11.	1.
3.50	35.	145.	17.	2.	7.	1.	4.	14.	1.
3.75	40.	158.	17.	2.	7.	1.	4.	15.	2.
4.00	42.	161.	17.	2.	6.	1.	4.	14.	1.
4.25	46.	164.	26.	2.	7.	2.	4.	14.	3.
4.50	56.	179.	52.	3.	9.	5.	6.	17.	8.
4.75	66.	192.	80.	3.	8.	6.	7.	18.	11.
5.00	70.	192.	97.	3.	7.	5.	7.	16.	11.
5.25	102.	217.	98.	7.	11.	3.	13.	21.	9.
5.50	182.	290.	85.	15.	19.	2.	26.	34.	5.
5.75	263.	364.	65.	17.	21.	1.	34.	41.	3.
6.00	311.	402.	46.	15.	18.	0.	33.	39.	1.
6.25	311.	389.	31.	10.	12.		26.	31.	0.
6.50	266.	327.	20.	5.	6.		16.	19.	
6.75	203.	248.	13.	2.	2.		9.	10.	
7.00	143.	174.	8.	1.	1.		4.	5.	
7.25	96.	116.	5.	0.	0.		1.	2.	
7.50	62.	74.	3.				1.	1.	
7.75	39.	47.	2.				0.	0.	
8.00	24.	29.	1.						
8.25	15.	17.	0.						
8.50	9.	11.							
8.75	5.	6.							
9.00	3.	4.							
9.25	1.	1.							
9.50	1.	1.							
9.75	0.	0.							

TABLE A-38 (cont)

RUNOFF HYDROGRAPHS

	King's Court			Tierrecito Vallejo Subarea A			Tierrecito Vallejo Subarea B		
Time in Hours	1 Percent Event	Standard Project Storm	100 Percent Event	1 Percent Event	Standard Project Storm	100 Percent Event	1 Percent Event	Standard Project Storm	100 Percent Event
0.00	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.25	0.	2.	0.	0.	1.	0.	0.	0.	0.
0.50	1.	7.	1.	0.	2.	0.	0.	1.	0.
0.75	1.	11.	1.	1.	5.	1.	0.	2.	0.
1.00	1.	12.	1.	1.	6.	1.	0.	3.	0.
1.25	2.	13.	2.	1.	8.	1.	0.	4.	0.
1.50	3.	15.	2.	1.	10.	1.	1.	4.	1.
1.75	3.	17.	2.	2.	11.	1.	1.	5.	1.
2.00	3.	16.	2.	2.	12.	2.	1.	5.	1.
2.25	4.	16.	2.	3.	13.	2.	1.	6.	1.
2.50	4.	18.	2.	3.	14.	2.	1.	6.	1.
2.75	4.	19.	2.	3.	15.	2.	1.	6.	1.
3.00	4.	19.	2.	3.	15.	2.	1.	7.	1.
3.25	5.	19.	2.	4.	16.	2.	2.	7.	1.
3.50	6.	22.	2.	4.	17.	2.	2.	7.	1.
3.75	6.	24.	3.	4.	18.	2.	2.	8.	1.
4.00	6.	24.	2.	5.	19.	2.	2.	8.	1.
4.25	7.	24.	5.	5.	19.	3.	2.	8.	1.
4.50	9.	27.	10.	6.	21.	5.	3.	9.	2.
4.75	11.	29.	15.	7.	22.	8.	3.	10.	3.
5.00	11.	28.	17.	8.	23.	10.	3.	10.	4.
5.25	18.	34.	15.	11.	25.	11.	5.	11.	5.
5.50	35.	50.	11.	18.	31.	10.	8.	14.	4.
5.75	49.	62.	7.	25.	38.	9.	11.	17.	4.
6.00	53.	64.	4.	32.	43.	7.	14.	19.	3.
6.25	47.	56.	2.	34.	45.	5.	15.	19.	2.
6.50	34.	41.	1.	32.	41.	4.	14.	18.	2.
6.75	22.	26.	0.	28.	34.	3.	12.	15.	1.
7.00	13.	15.		22.	27.	2.	10.	12.	1.
7.25	7.	8.		17.	20.	1.	7.	9.	0.
7.50	4.	4.		12.	15.	1.	5.	6.	
7.75	1.	2.		9.	10.	0.	4.	4.	
8.00	1.	1.		6.	7.		3.	3.	
8.25	0.	0.		4.	5.		1.	1.	
8.50				3.	3.		1.	1.	
8.75				1.	1.		0.	0.	
9.00				1.	1.				
9.25				0.	0.				

TABLE A-38 (cont)

RUNOFF HYDROGRAPHS

	Brook's Addition			Talbot's Nursery			Country Club Acres		
Time in Hours	1 Percent Event	Standard Project Storm	100 Percent Event	1 Percent Event	Standard Project Storm	100 Percent Event	1 Percent Event	Standard Project Storm	100 Percent Event
0.00	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.25	1.	7.	1.	0.	1.	0.	0.	2.	0.
0.50	3.	27.	3.	1.	5.	1.	1.	9.	1.
0.75	7.	51.	7.	1.	9.	1.	2.	18.	2.
1.00	9.	74.	9.	2.	12.	2.	3.	27.	3.
1.25	13.	96.	12.	2.	15.	2.	5.	35.	4.
1.50	18.	120.	15.	3.	18.	2.	7.	45.	6.
1.75	24.	141.	18.	4.	20.	3.	9.	53.	7.
2.00	28.	154.	20.	4.	21.	3.	11.	59.	8.
2.25	32.	166.	22.	5.	22.	3.	12.	64.	9.
2.50	37.	181.	24.	5.	24.	3.	14.	71.	9.
2.75	41.	196.	26.	6.	25.	3.	16.	76.	10.
3.00	44.	203.	26.	6.	26.	3.	17.	80.	10.
3.25	47.	212.	27.	6.	27.	3.	19.	84.	11.
3.50	53.	229.	28.	7.	29.	3.	21.	90.	11.
3.75	59.	246.	29.	8.	31.	3.	23.	97.	11.
4.00	63.	256.	28.	8.	32.	3.	25.	101.	11.
4.25	70.	267.	37.	9.	33.	5.	27.	106.	14.
4.50	81.	286.	60.	11.	36.	9.	31.	113.	23.
4.75	93.	304.	90.	13.	38.	15.	36.	120.	33.
5.00	103.	313.	117.	14.	39.	18.	40.	124.	44.
5.25	135.	341.	133.	19.	43.	19.	52.	135.	50.
5.50	212.	412.	134.	33.	56.	17.	79.	161.	52.
5.75	305.	496.	124.	49.	70.	14.	113.	191.	49.
6.00	385.	564.	107.	59.	78.	11.	144.	218.	44.
6.25	431.	594.	88.	61.	78.	8.	163.	231.	37.
6.50	430.	572.	69.	55.	69.	5.	167.	227.	30.
6.75	394.	513.	53.	45.	55.	4.	157.	208.	24.
7.00	339.	435.	40.	33.	41.	2.	139.	182.	19.
7.25	278.	353.	30.	24.	29.	1.	118.	152.	14.
7.50	219.	277.	22.	16.	20.	1.	96.	123.	11.
7.75	168.	211.	16.	11.	13.	0.	76.	97.	8.
8.00	126.	159.	11.	7.	9.		59.	75.	6.
8.25	93.	117.	8.	5.	5.		45.	57.	4.
8.50	69.	86.	6.	3.	3.		34.	43.	3.
8.75	50.	62.	4.	1.	1.		26.	32.	2.
9.00	36.	45.	3.	1.	1.		19.	24.	2.
9.25	26.	32.	2.	0.	0.		14.	17.	1.
9.50	19.	23.	1.				11.	13.	1.
9.75	13.	16.	1.				7.	9.	0.
10.00	9.	12.	1.				6.	7.	
10.25	7.	8.	0.				4.	4.	
10.50	5.	6.					3.	3.	
10.75	3.	4.					1.	1.	
11.00	2.	3.					1.	1.	
11.25	1.	1.					0.	0.	
11.50	1.	1.							
11.75	0.	0.							

TABLE A-38 (cont)

RUNOFF HYDROGRAPHS

Time in Hours	Damsite Road Raise Upstream 1 Percent Event	Standard Project Storm	100 Percent Event	Downstream 1 Percent Event	Standard Project Storm	100 Percent Event	Johnson's Addition 1 Percent Event	Standard Project Storm	100 Percent Event
0.00	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.25	0.	3.	0.	0.	3.	0.	1.	6.	1.
0.50	1.	11.	1.	1.	11.	1.	3.	20.	3.
0.75	3.	20.	3.	2.	18.	2.	4.	34.	4.
1.00	4.	29.	4.	3.	21.	3.	5.	41.	5.
1.25	5.	36.	5.	3.	23.	3.	6.	47.	6.
1.50	7.	45.	6.	5.	27.	3.	8.	49.	6.
1.75	9.	52.	7.	6.	29.	4.	11.	56.	7.
2.00	10.	56.	7.	6.	28.	4.	12.	54.	8.
2.25	12.	59.	8.	6.	28.	4.	13.	57.	8.
2.50	13.	64.	9.	7.	32.	4.	13.	58.	8.
2.75	15.	69.	8.	8.	34.	4.	15.	66.	9.
3.00	16.	71.	9.	8.	33.	4.	15.	64.	8.
3.25	17.	74.	9.	8.	33.	4.	16.	68.	8.
3.50	19.	80.	10.	10.	39.	4.	18.	71.	8.
3.75	21.	86.	10.	11.	43.	4.	21.	83.	9.
4.00	22.	89.	10.	11.	42.	4.	22.	82.	8.
4.25	25.	93.	13.	12.	42.	8.	25.	86.	15.
4.50	29.	100.	22.	16.	48.	18.	29.	88.	31.
4.75	33.	106.	34.	19.	51.	26.	36.	100.	49.
5.00	37.	108.	44.	19.	49.	29.	37.	96.	57.
5.25	49.	119.	49.	31.	59.	26.	59.	116.	56.
5.50	79.	146.	48.	60.	86.	20.	107.	155.	37.
5.75	115.	179.	42.	84.	108.	13.	158.	205.	27.
6.00	144.	203.	35.	91.	112.	7.	180.	221.	13.
6.25	157.	210.	28.	82.	99.	4.	174.	210.	8.
6.50	152.	197.	21.	61.	72.	2.	115.	138.	5.
6.75	134.	171.	15.	39.	47.	1.	83.	99.	3.
7.00	111.	139.	11.	23.	27.	0.	42.	50.	2.
7.25	87.	109.	8.	13.	15.		25.	30.	1.
7.50	66.	82.	6.	7.	8.		15.	17.	0.
7.75	48.	60.	4.	4.	4.		9.	10.	
8.00	35.	43.	3.	1.	2.		5.	6.	
8.25	25.	30.	2.	1.	1.		3.	3.	
8.50	17.	21.	1.	0.	0.		1.	1.	
8.75	12.	15.	1.				1.	1.	
9.00	8.	10.	0.				0.	0.	
9.25	6.	7.							
9.50	4.	5.							
9.75	3.	3.							
10.00	1.	1.							
10.25	1.	1.							
10.50	0.	0.							

TABLE A-38 (cont)

RUNOFF HYDROGRAPHS

Time in Hours	Sawyer 1 Percent Event	Sawyer Standard Project Storm	Sawyer 100 Percent Event	Velva 1 Percent Event	Velva Standard Project Storm	Velva 100 Percent Event
0.00	0.	0.	0.	See Tables A-18 through A-43, Pages A-47 through A-73 Design Memorandum No. 4		
0.25	0.	4.	0.			
0.50	2.	12.	2.			
0.75	3.	21.	3.			
1.00	3.	26.	3.			
1.25	4.	30.	4.			
1.50	6.	35.	4.			
1.75	7.	38.	5.			
2.00	8.	38.	5.			
2.25	8.	39.	5.			
2.50	9.	43.	6.			
2.75	10.	46.	6.			
3.00	10.	45.	6.			
3.25	11.	46.	6.			
3.50	13.	52.	6.			
3.75	15.	57.	6.			
4.00	15.	57.	6.			
4.25	16.	58.	10.			
4.50	21.	64.	21.			
4.75	24.	69.	31.			
5.00	26.	68.	37.			
5.25	39.	78.	36.			
5.50	71.	108.	29.			
5.75	102.	137.	21.			
6.00	117.	148.	14.			
6.25	113.	139.	9.			
6.50	91.	111.	5.			
6.75	66.	79.	3.			
7.00	43.	52.	2.			
7.25	27.	33.	1.			
7.50	16.	19.	0.			
7.75	10.	11.				
8.00	6.	7.				
8.25	3.	4.				
8.50	1.	1.				
8.75	1.	1.				
9.00	0.	0.				

TABLE A-39

GRAVITY OUTLET DESIGN

Study Area	Required[1] Outlet Size (diam. in Inches	Length In Feet	Pipe Invert Elevations At Inlet	Pipe Invert Elevations At Outlet	Required[2] Gate Type
UPSTREAM OF LAKE DARLING OUTLET STRUCTURE					
Renville County Park	90	140	1591.0	1590.0	S
McKinney Cemetery	24	104	1596.5	1596.0	F
Eckert's Ranch	36	110	1596.5	1596.0	F
WEST OF PROPOSED ROAD RAISE					
Upstream of Outlet Structure	36	110	1600.0	1599.0	F
Downstream of Outlet Structure	24	140	1595.0	1594.0	F
OUTLET STRUCTURE DOWNSTREAM TO MINOT					
Johnson's Addition	24	90	1560.0	1559.7	S
Brooks' Addition	36	73	1557.0	1556.8	S
Talbot's Nursery	24	72	1556.0	1555.8	S
Country Club Acres and Robinwood Estates	24	83	1555.0	1554.7	S
King's Court and Rastad's Addition	24	77	1553.6	1553.0	S
Tierrecito Vallejo					
Subarea A (Outlet No. 1)	24	64	1550.0	1549.8	S
Subarea B (Outlet No. 2)	24	42	1555.0	1554.8	S
SAWYER	24	375	1510.0	1508.9	S
VELVA[3]					
Area A	90	296	1491.0	1491.0	S
Area B	90	139	1490.0	1490.0	S
Area C	Twin 48	50	1513.5	1513.5	F
Area D	36	108	1496.7	1496.7	S
Area E	24	222	1495.0	1495.0	S
Area F	36	35	1506.0	1506.0	F
Area G	24	35	1507.3	1507.3	F

(1) All pipes will be reinforced concrete.
(2) Flap gate (F) or gatewell with sluice gate (S).
(3) For more details, see Design Memorandum No. 4, Appendix A.

TABLE A-39 (cont)

GRAVITY OUTLET DESIGN (CONT.)

Study Area	Peak Inflow Rates in CFS: 1 Percent Event	Peak Inflow Rates in CFS: SPS	Accumulated Inflow in Acre-Feet: 1 Percent Event	Accumulated Inflow in Acre-Feet: SPS	Selected Ponding Elevations: Stage C	Selected Ponding Elevations: Stage D	Available Storage in Acre-Feet: Stage C	Available Storage in Acre-Feet: Stage D	Peak Discharge in CFS at Stage C Level: Required	Peak Discharge in CFS at Stage C Level: Available	Peak Discharge in CFS at Stage D Level: Required	Peak Discharge in CFS at Stage D Level: Available
UPSTREAM OF LAKE DARLING OUTLET STRUCTURE												
Renville County Park	311	402	70.3	124.1	1599.0	1600.0	42.0	58.0	125	452	214	522
McKinney Cemetery	17	21	2.8	4.9	1601.0	1602.0	0	0	17	17	21	24
Eckert's Ranch	34	41	6.0	10.6	1599.0	1600.0	2.2	3.3	22	29	28	41
WEST OF PORPOSED ROAD RAISE												
Upstream of Outlet Structure	157	210	41.8	73.7	1611.0	-	14.5	-	103	103	-	-
Downstream of Outlet Structure	84	112	17.7	31.3	1605.0	-	32.0	-	0	40	-	-
OUTLET STRUCTURE DOWNSTREAM TO MINOT												
Johnson's Addition	180	221	38.9	68.7	1567.5	1569.0	44.0	60.0	0	41	28	45
Brooks' Addition	431	594	123.2	217.5	1569.0	1570.0	125.0	175.0	0	110	116	116
Talbot's Nursery	61	78	14.5	25.6	1565.5	1567.0	39.0	50.0	0	43	0	45
Country Club Acres and Robinwood Estates	167	231	50.0	88.3	1563.0	1564.0	82.0	104.0	0	40	0	42
King's Court and Rastad's Addition	53	64	10.2	17.9	1562.0	1563.0	4.0	8.0	32	40	35	47
Tierrecito Vallejo												
Subarea A (Outlet No. 1)	34	45	8.6	15.3	1558.0	1559.0	49.0	96.0	0	40	0	42
Subarea B (Outlet No. 2)	15	19	3.8	6.7	1558.0	1559.0	4.5	19.0	0	20	0	27
SAWYER	117	148	24.8	43.7	1522.0	1523.0	41.0	52.0	0	32	0	33
VELVA - Area A												

TABLE A-40

PUMPING STATION DESIGN

Study Area	Percent Time of Blocked Gravity Drainage	Peak Inflow Rate in cfs 100 Percent Event	Accumulated Inflow in Acre Feet: 100 Percent Event	Accumulated Inflow in Acre Feet: 50 Percent Event	Accumulated Inflow in Acre Feet: 20 Percent Event	Selected Gate Closure Elevation	Available Storage in Acre Feet: Below Gate Closure Level	Available Storage in Acre Feet: Between Stage C and Gate Closure Levels	Required Pumping Capacity in GPM Less Seepage	Recommended Pumping Facilities: Design Capacity in GPM	Recommended Pumping Facilities: Type
UPSTREAM OF LAKE DARLING OUTLET STRUCTURE											
Renville County Park	Less than 1	98	22.6	29.2	39.4	1597.0	13	29.0	0	3000	Permanent
McKinney Cemetery	Less than 1	6	0.9	1.2	1.6	1600.0	0	0	2700	3000	Portable
Eckert's Ranch	Less than 1	11	2.0	2.5	3.4	1597.0	0.6	1.6	990	1300	Portable
WEST OF PROPOSED ROAD RAISE											
Upstream of Outlet Structure	Less than 1	49	13.4	17.4	23.4	1603.0	0.5	14.0	0	None	-
Downstream of Outlet Structure	Less than 1	29	5.7	7.4	10.0	1597.0	1.6	30.4	0	None	-
OUTLET STRUCTURE DOWNSTREAM TO MINOT											
Johnson's Addition	Less than 1	57	12.5	16.2	-	1565.5	22.5	21.5	0	3000	Permanent
Brooks' Addition	Less than 1	134	39.6	51.2	-	1567.0	85.0	40.0	0	3000	Permanent
Talbot's Nursery	Less than 1	19	4.7	6.0	-	1563.5	27.0	12.0	0	3000	Permanent
Country Club Acres and Robinwood Estates	2.0	52	16.1	20.8	-	1561.0	48.0	34.0	0	3000	Permanent
King's Court and Rastad's Addition	2.3	17	3.3	4.2	5.7	1560.0	0	4.0	0	3000	Permanent
Tierrecito Vallejo											
Subarea A (Outlet No. 1)	Less than 1	11	2.8	3.6	-	1557.0	34.0	15.0	0	3000	Permanent
Subarea B (Outlet No. 2)	Less than 1	5	1.2	1.6	-	1557.0	1.0	3.5	0	3000	Permanent
SAWYER	6.3	37	8.0	10.3	13.9 (1)	1512.0	2.8	38.2	0	3000	Permanent
VELVA - Area A	-	-	-	-	-	1501.0	-	-	-	5000	Permanent

(1) Accumulated inflow from a 10 percent event is about 16.5 acre feet.

239. Both flap gates and gatewells with sluice gates are used. Gatewells with sluice gates are recommended at outlets located in areas containing residential development and subject to a significant amount of flood damage should a gate malfunction. Flap gates are recommended where there is no residential development and/or the resulting flood damage from a malfunctioning gate would be minimum.

240. The peak inflow rates indicated in Table A-39 were obtained from the runoff hydrographs presented in Table A-38 . The accumulated inflow volumes were obtained by multiplying the accumulated 96-hour rainfall excess amounts (presented on Plates A-97 and A-98) by the contributing watersheds (presented in Table A-36) and converting this volume to acre feet. The indicated stage C and stage D ponding elevations were selected based on criteria presented in EM 1110-2-1410. The available storage below the selected ponding-elevations was obtained from the elevation-area-capacity curves presented on Plates A-84 through A-88 .

241. The required capacity of the gravity outlets was obtained using the following equation:

$$Q_o = Q_I \frac{(V_I - V_S)}{V_I}$$

Where:

Q_o = Peak outflow rate in cfs

Q_I = Peak inflow rate in cfs

V_I = Volume of runoff in acre feet

V_S = Volume of storage in acre feet

242. The available outlet capacity was obtained using the standard culvert design criteria presented in EM 1110-345-284 and assuming a low river or reservoir pool level, a Manning's "n" of 0.015 (RCP), and an entrance coefficient (K_e) of 0.5. Pipe sizes were selected to maintain the water surface at or near the stage C level for the one percent storm assuming a free fall condition, except for the proposed 90-inch outlet at Renville Park which will be submerged at all times. The minimum culvert diameter was established as 24 inches for outlet structures and 18 inches for interior culverts and stormsewers.

243. Drainage ditches, where required, will have 1 on 3 side slopes and a minimum bottom width of 2 feet for ease of maintenance. A minimum ditch slope of about 0.3 percent is recommended where ever practicable to maintain positive drainage without extensive maintenance.

244. It is assumed that the existing storm sewers and ditches that form a vital part of the proposed plans will continue to be maintained and that there are no current plans for any major alterations to any of the existing drainage facilities other than those proposed in this report.

245. Pumping Station Design

Recommended capacities and types of pumping station along with pertinent design data are presented in Table A-40 . As indicated in Table A-40 , the estimated duration of blocked gravity drainage in all areas, except the Country Club, King's Court and Sawyer areas, will be less than one percent of the time. The estimated duration of blocked gravity drainage in the Country Club, King's Court and Sawyer areas will be about 2.0, 2.3 and 6.3 percent of the time, respectively.

246. The selected gate closure elevations were assumed to be an elevation two feet below the selected stage C ponding level in all areas, except in the McKinney Cemetery, the areas west of the proposed road raise and in the Sawyer area. In the cemetery, a gate closure elevation one foot below the stage C level was selected because of the small magnitude of flood damage that could occur with a gate failure. In the remaining three areas, the selected gate closure level is equal to the crown of the outlet structure to prevent unsafe pond depths landward of the outlet.

247. The required size of pumping facilities (less storage) was assumed to be the capacity required to remove the runoff from a rainfall event having a frequency of occurrence of 100 events in 100 years in all areas where the estimated duration of blocked gravity drainage is one percent or less. Where the duration of blocked gravity drainage is greater than one percent, a rainfall event having a reciprocal frequency of occurrence in events per 100 years was used. The peak inflow rates, accumulated inflow volumes, available storage volumes and required pumping capacities indicated in Table A-40 were obtained in the same manner as for the design of the gravity outlets presented in Table A-39 , except that the design pumping rate was converted from cfs to gpm. For the required pumping rate in the Country Club, King's Court and Sawyer areas, a peak inflow rate was interpolated from the peak rates obtained for the 100-percent event using the total rainfall excess values presented on Plates A-92 , A-93 and A-94.

248. Pumping facilites are recommended in all areas, except west of the proposed road raise, because there may not be sufficient pondage to contain seepage and/or subsequent rainfall during a period of blocked gravity drainage. Except in the Eckert's Ranch area, where the contributing watershed and potential damages are relatively small, no design pumping capacity less than 3000 gpm is recommended. A 3000 gpm capacity station was considered to be the most economical size. Also with a 3000 gpm design capacity, all ponding areas could be emptied in about 3 days.

249. Because of the high clay content in the area, seepage volumes during periods of blocked gravity drainage are assumed to be relatively small.

250. Where there exists residential development, permanent pumping stations are recommended because past experience has shown that the temporary use of portable pumps is unreliable during emergency operations. The responsible local authorities have not always provided for the proper maintenance and storage of portable pumps. In areas where there is no significant development and the potential for major flood damages does not exist, the use of portable pumps is recommended. Each permanent pumping station is assumed to contain a sump chamber, intake chamber, sluice gate, trash rack and a reinforced concrete superstructure to house the pump motors and electrical controls.

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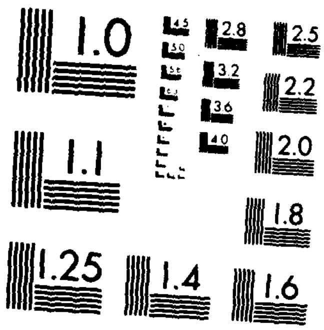
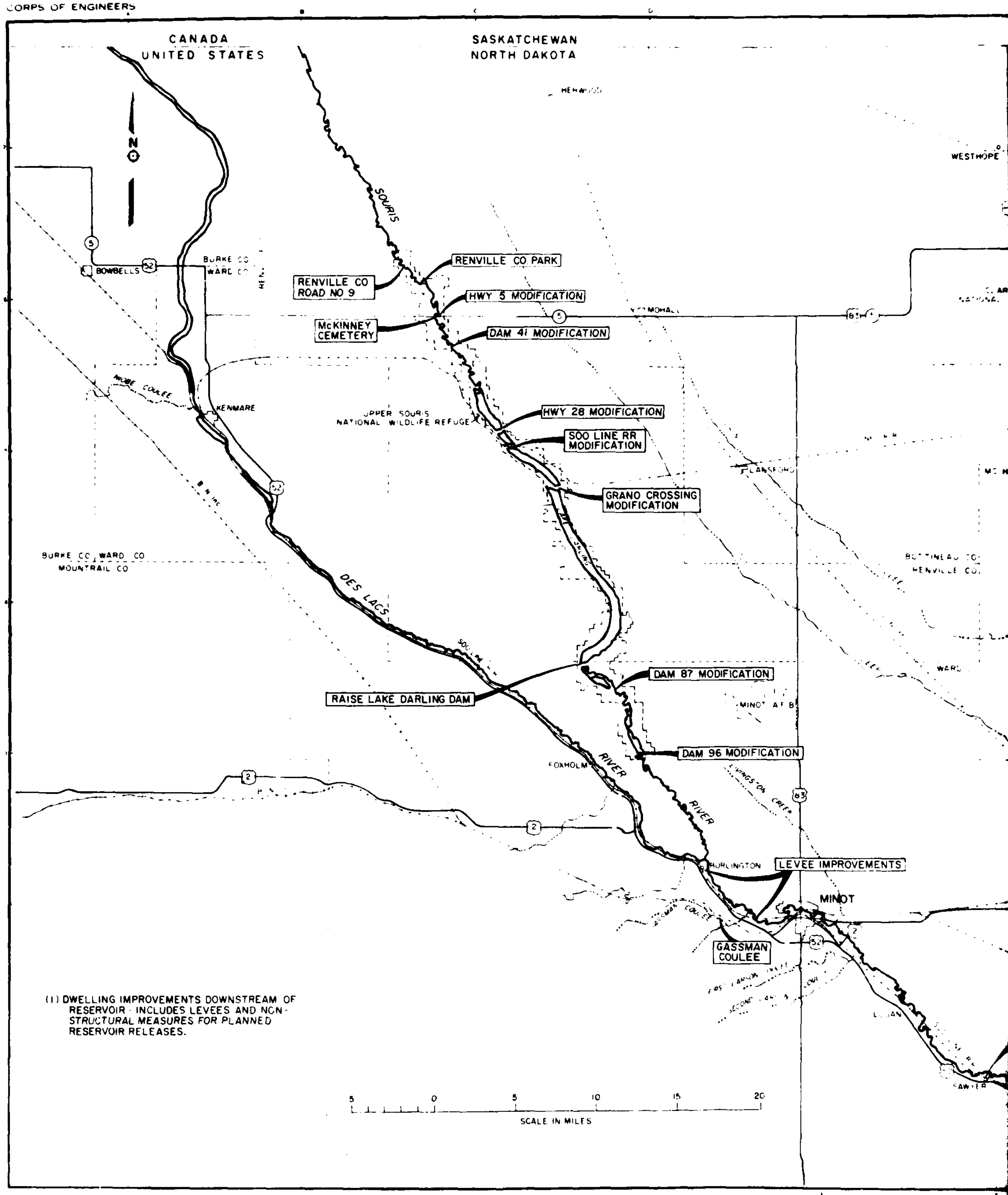


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

CORPS OF ENGINEERS



U. S. ARMY

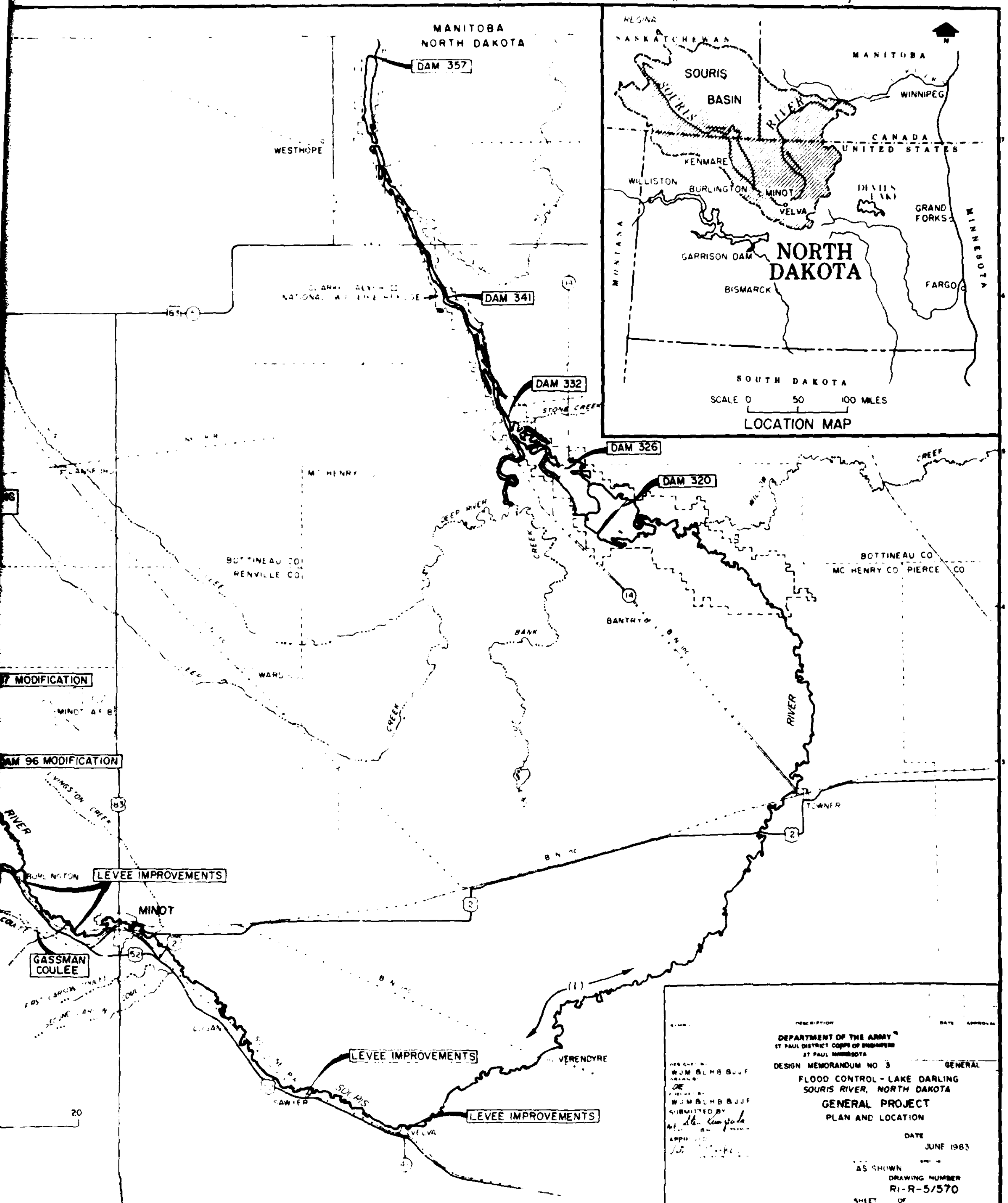
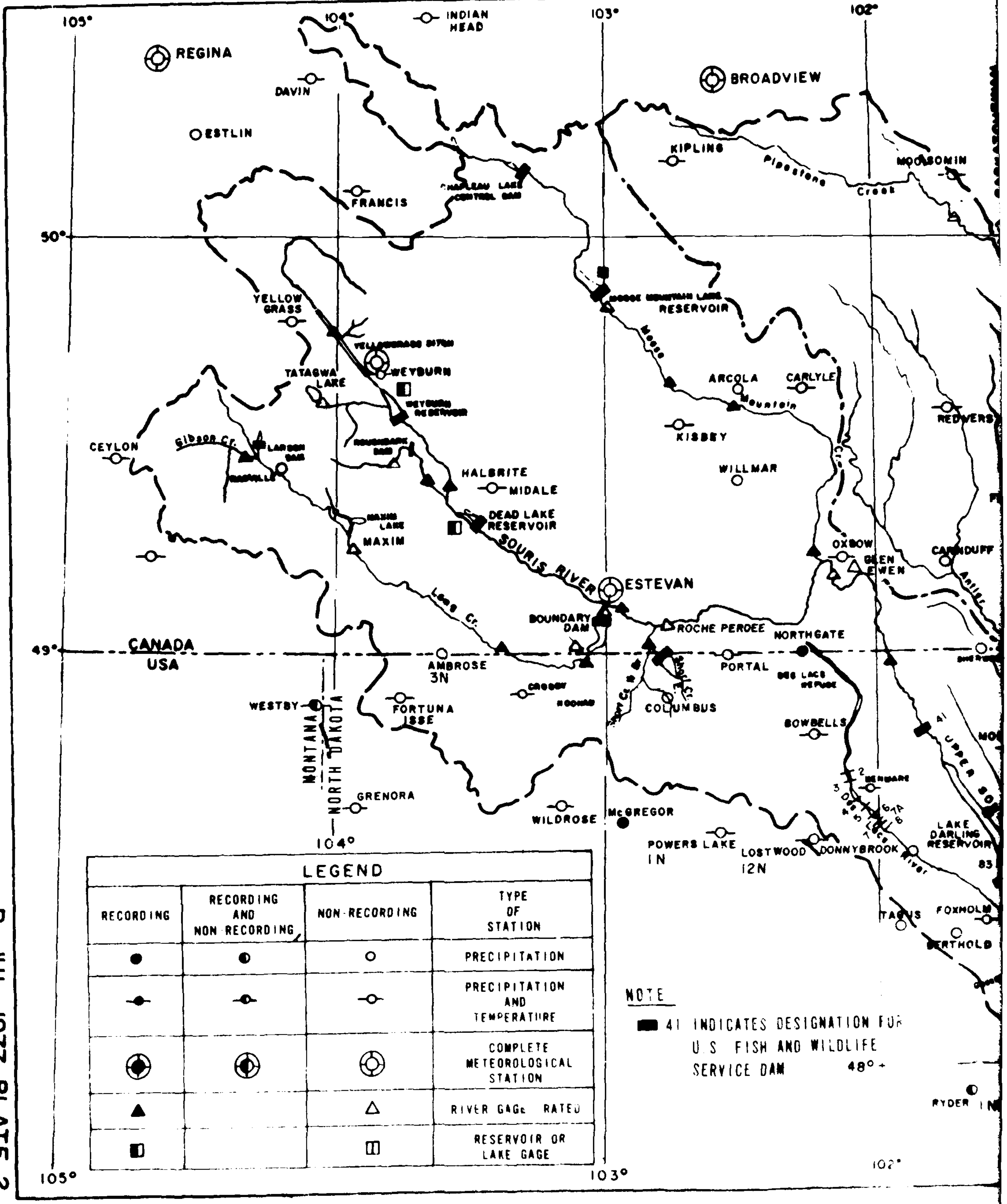


PLATE A-1

2



R-JUL-1977 PLATE 2

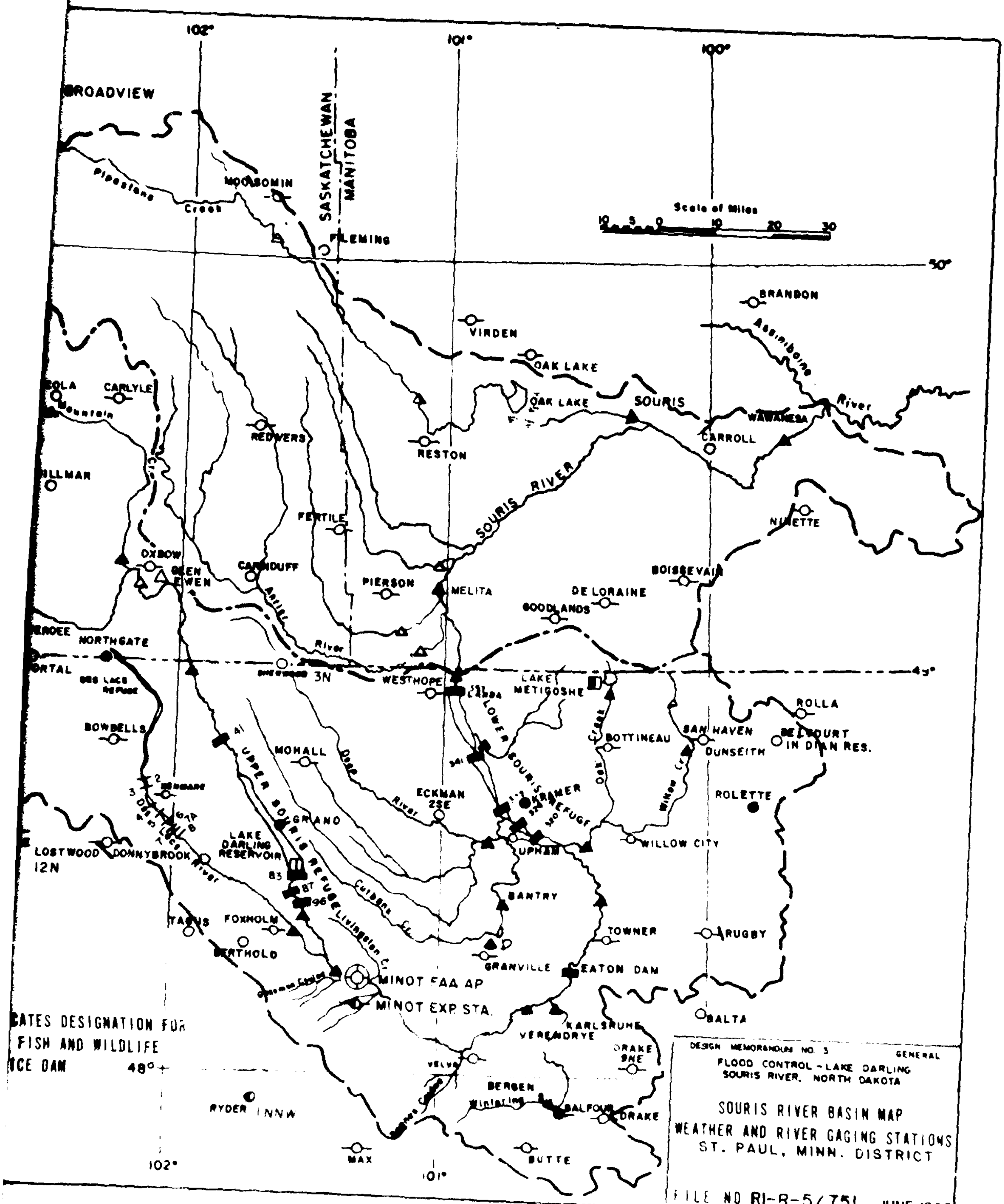
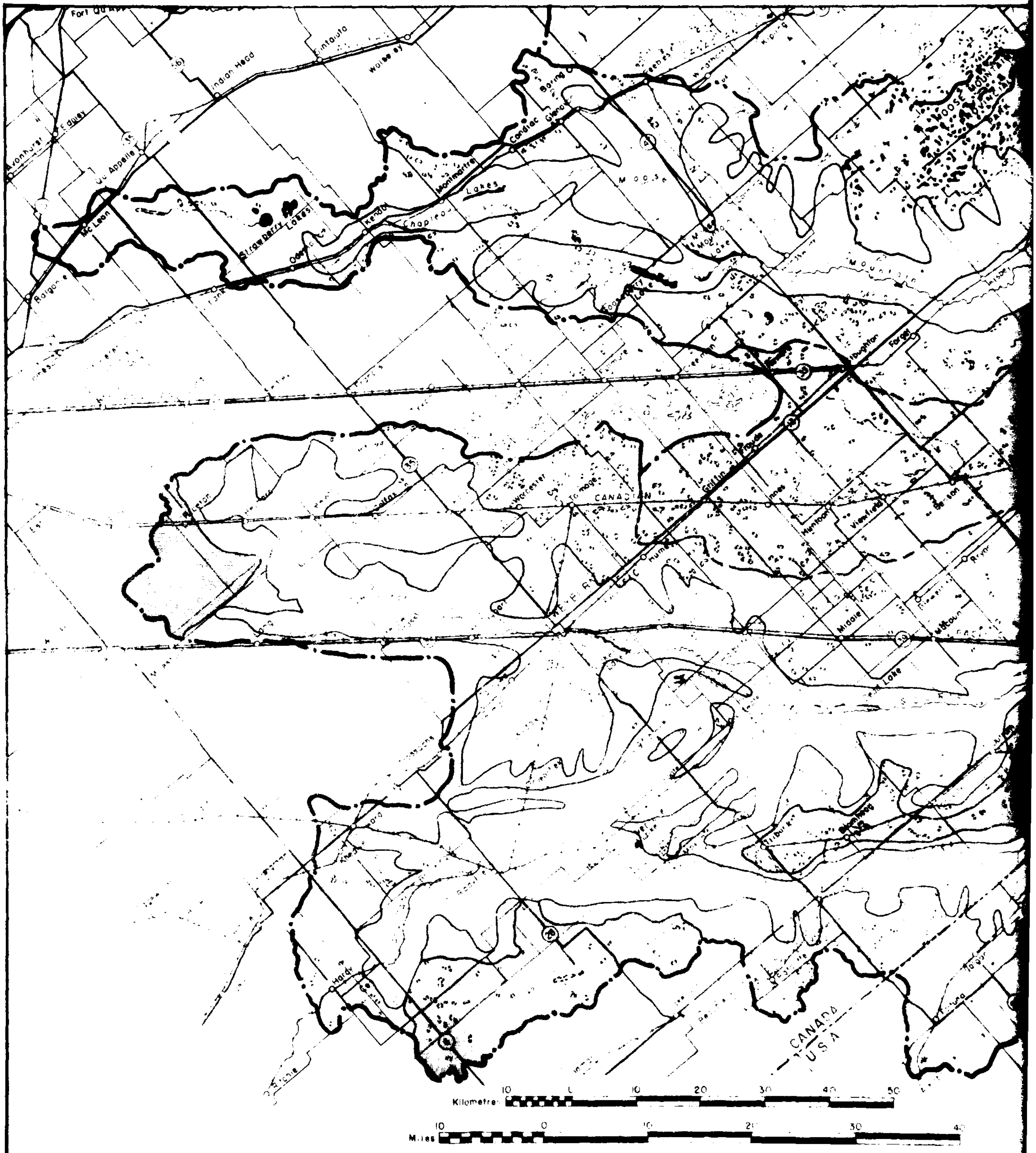

DESIGN MEMORANDUM NO. 3
GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
SOURIS RIVER BASIN MAP
WEATHER AND RIVER GAGING STATIONS
ST. PAUL, MINN. DISTRICT
FILE NO RI-R-5/751
JUNE 1983
Scale of Miles
10 5 0 10 20 30
102°
101°
100°
50°
49°
48°
SASKATCHEWAN
MANITOBA
BROADVIEW
MOOSOMIN
FLEMING
Pipestone
Creek
BRANDON
VIRDEN
OAK LAKE
Assiniboine
River
SOURIS
WAWANESA
CARROLL
RESTON
REDVERS
CARLYLE
HILLMAR
SOURIS RIVER
FERTILE
NINETTE
OXBOW
GLEN EWEN
CARNDUFF
PIERSON
MELITA
BOISSEVAIN
DE LORAINE
GOODLANDS
NORTHGATE
Antler
River
SHERWOOD 3N
WESTHOPE
LAKE METIGOSHE
ROLLA
BOWBELLS
MOHALL
LOWER SOURIS REFUGE
BOTTINEAU
SAN HAVEN
DUNSEITH
BELCOURT IN DIAN RES.
UPPER SOURIS REFUGE
ECKMAN 2SE
KRAMER
ROLETTE
GRANO
Deep
River
LAKE DARLING RESERVOIR
UPHAM
WILLOW CITY
LOSTWOOD 12N
DONNYBROOK
Des Lacs River
BANTRY
TAGUS
FOXHOLM
Livingston Cr.
TOWNER
RUGBY
BERTHOLD
GRANVILLE
MINOT FAA AP
EATON DAM
MINOT EXP. STA.
BALTA
KARLSRUHE
VERENDRYE
DRAKE 9NE
VELVA
BERGEN
Wintering
BALFOUR
DRAKE
RYDER 1NNW
MAX
BUTTE
ATES DESIGNATION FOR
FISH AND WILDLIFE
ICE DAM

PLATE A-2

2



Indian Head
Sintaluta
Wolseley
Qu Appelle
McLean
Balgonie
Strawberry Lakes
Kendal
Montmartre
Chapleau
Lakes
Candiac
Kipling
MOOSE MOUNTAIN
Worcester
CANADIAN
Griffin
Froude
Viewfield
Stoughton
Forget
Middale
Lake
Tribune
Hardy
CANADA
U.S.A.
Kilometres
10 0 10 20 30 40 50
Miles
10 0 10 20 30 40

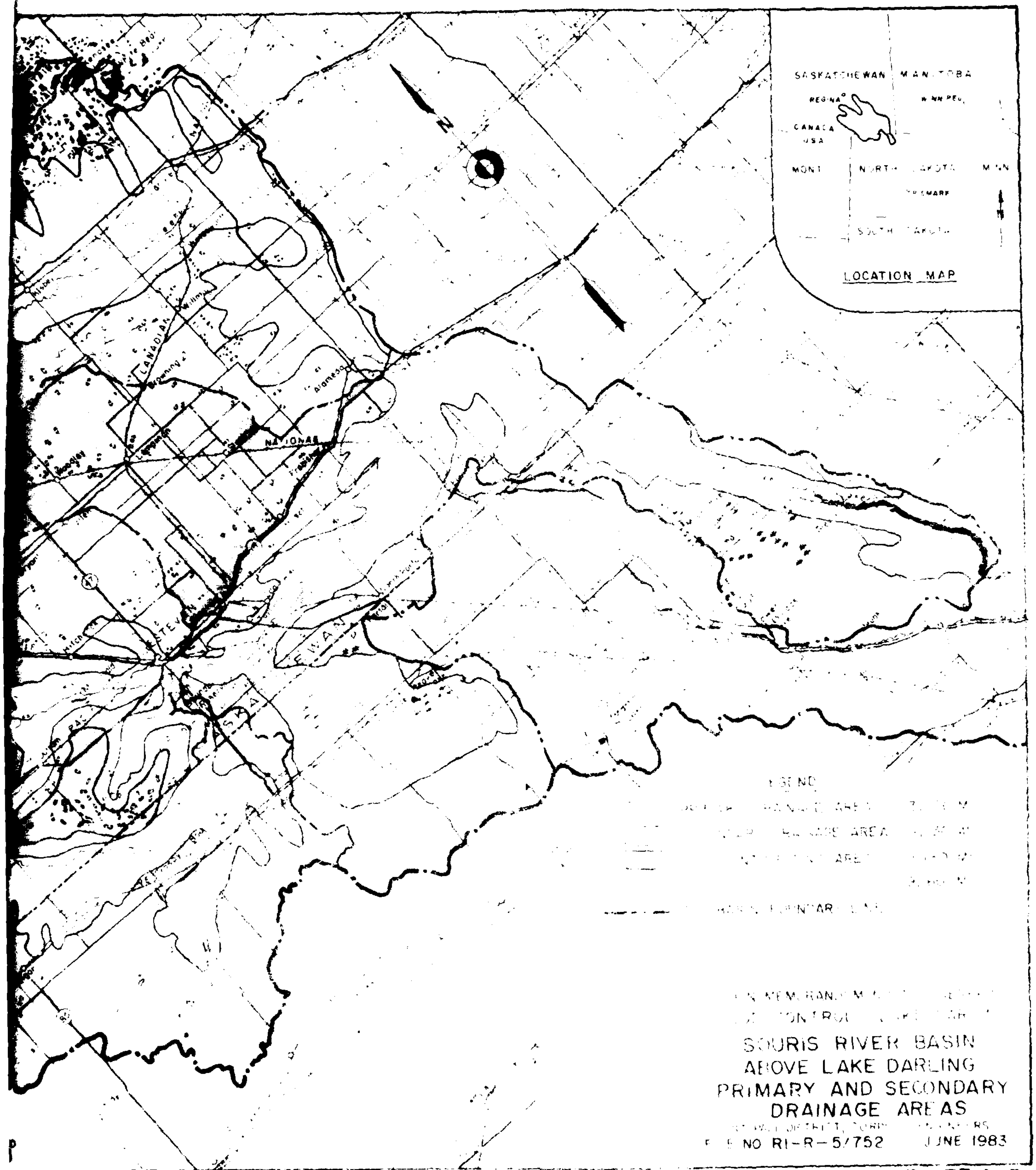
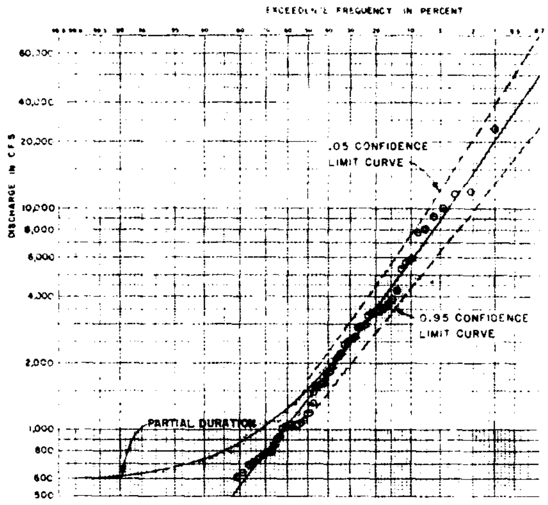

SASKATCHEWAN
MANITOBA
REGINA
CANADA
USA
MONT
NORTH DAKOTA
MINN
SOUTH DAKOTA
LOCATION MAP
LEGEND
CANADIAN
NATIONAL
SOURIS RIVER BASIN
ABOVE LAKE DARLING
PRIMARY AND SECONDARY
DRAINAGE AREAS
JUNE 1983

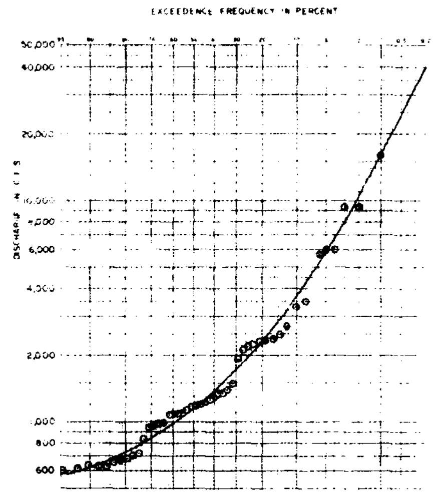
PLATE A-3

1 2



DISCHARGE FREQUENCY CURVES
SOURIS RIVER ABOVE MINOT, N D
NATURAL CONDITIONS

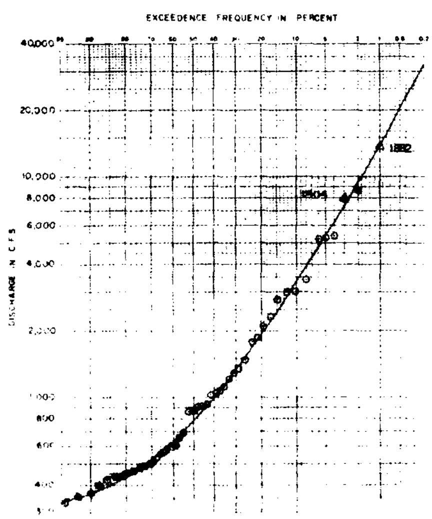
NOTE:
ANNUAL AND PARTIAL DURATION, INSTANTANEOUS PEAKS



DISCHARGE FREQUENCY CURVE
SOURIS RIVER ABOVE MINOT, N D
EXISTING CONDITIONS

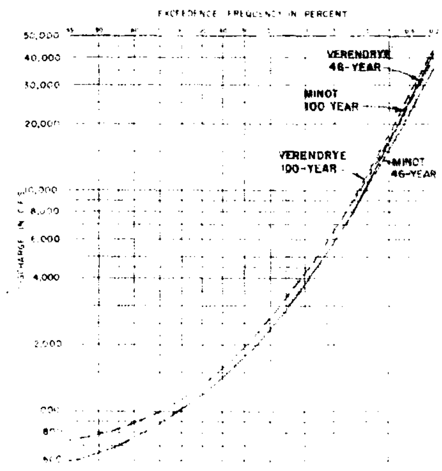
NOTE
PARTIAL DURATION, INSTANTANEOUS PEAKS

NOTE



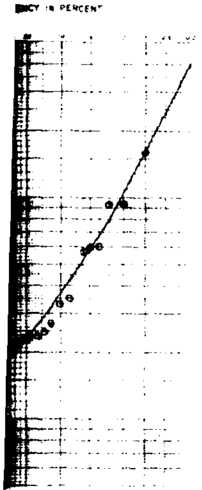
DISCHARGE FREQUENCY CURVE
SOURIS RIVER NEAR FOXHOLM, N D
EXISTING CONDITIONS

NOTE
PARTIAL DURATION INSTANTANEOUS PEAKS



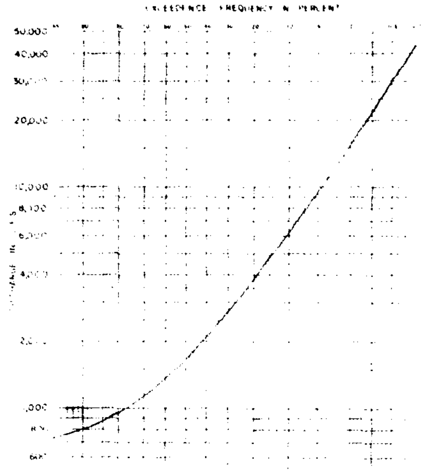
DISCHARGE FREQUENCY CURVE
SOURIS RIVER NEAR VERENDRYE, N D
EXISTING CONDITIONS
ADJUSTMENT 46-YEAR TO 100 YEAR PERIOD

NOTE
PARTIAL DURATION INSTANTANEOUS PEAKS



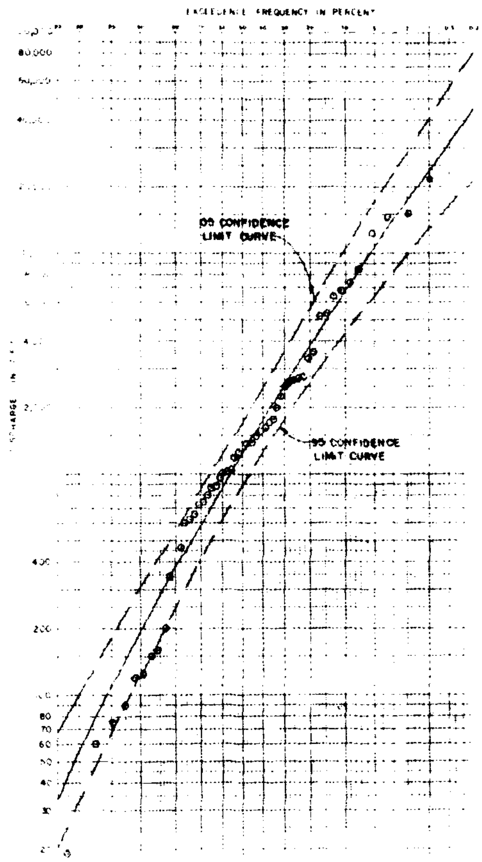
FREQUENCY CURVE
ABOVE MINOT, N.D
CONDITIONS

INSTANTANEOUS PEAKS

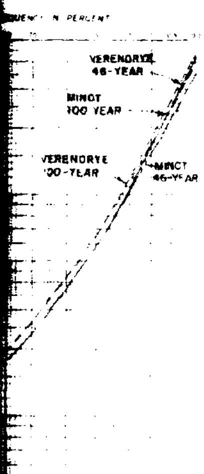


DISCHARGE FREQUENCY CURVE
SOURIS RIVER NEAR VERENDRYE N.D
NATURAL CONDITIONS

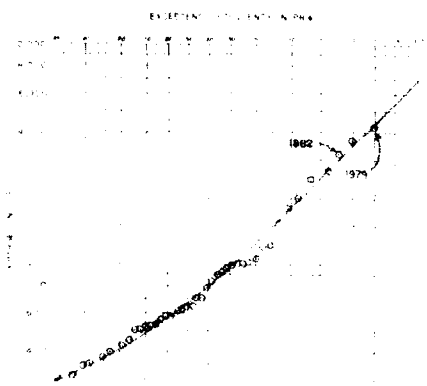
NOTE
PARTIAL DURATION, INSTANTANEOUS PEAKS



DISCHARGE FREQUENCY CURVES
SOURIS RIVER NEAR SHERWOOD N.D
NOTE
ANNUAL INSTANTANEOUS PEAKS



FREQUENCY CURVE



NOTE
PARTIAL DURATION, INSTANTANEOUS PEAKS

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

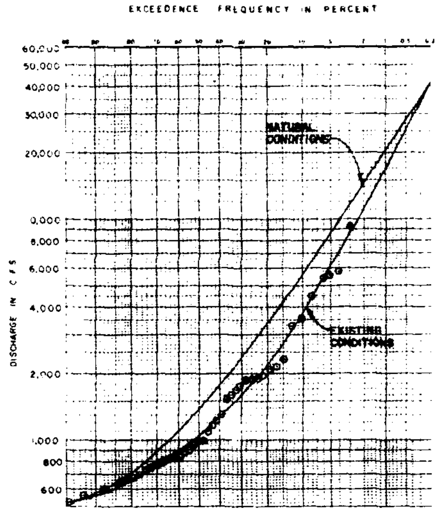
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
DISCHARGE FREQUENCY CURVES
SOURIS AND DES LACS RIVERS
NATURAL AND EXISTING CONDITIONS

DESIGNED BY
DRAWN BY
CHECKED BY
SUBMITTED BY
APPROVED

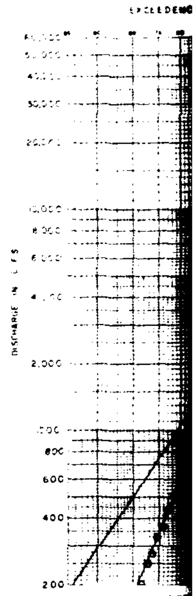
DATE JUNE 1983
SCALE AS SHOWN
DRAWING NUMBER RI-R-5/753
SHEET OF

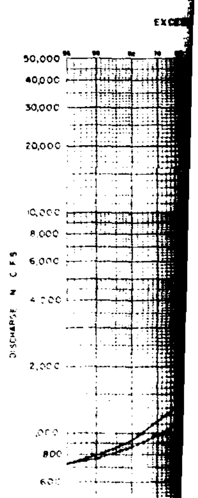
PLATE A-4

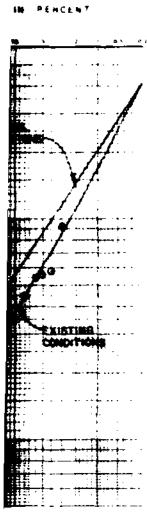
1 2

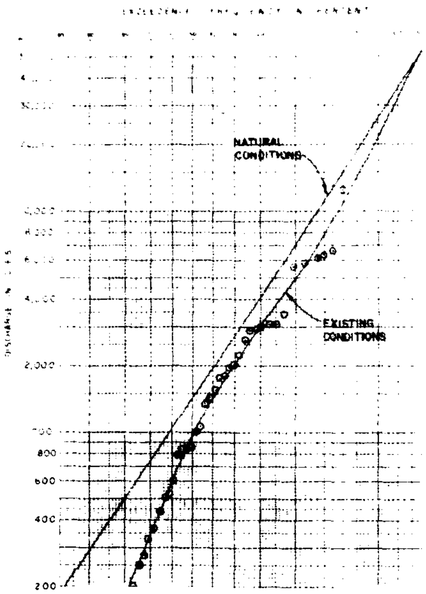


DISCHARGE FREQUENCY CURVES
SOURIS RIVER NEAR BANTRY, N D
NOTE: PARTIAL DURATION MEAN DAILY PEAKS

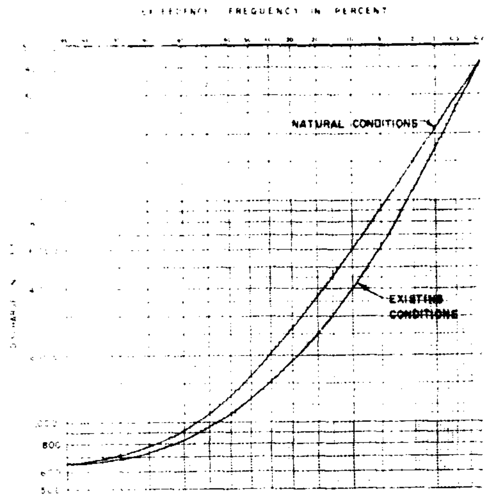




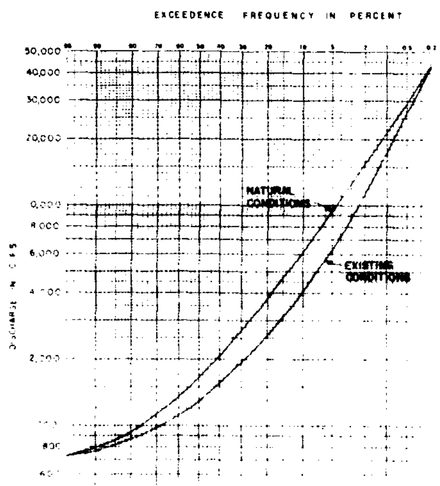




DISCHARGE FREQUENCY CURVES
SOURIS RIVER NEAR WEST HOPE, N D
NOTE
ANNUAL MEAN DAILY PEAKS



DISCHARGE FREQUENCY CURVES
SOURIS RIVER NEAR SAWYER, N D
NOTE
PARTIAL DURATION, INSTANTANEOUS PEAKS



DISCHARGE FREQUENCY CURVES
SOURIS RIVER AT VELVA, N D
NOTE
PARTIAL DURATION, INSTANTANEOUS PEAKS

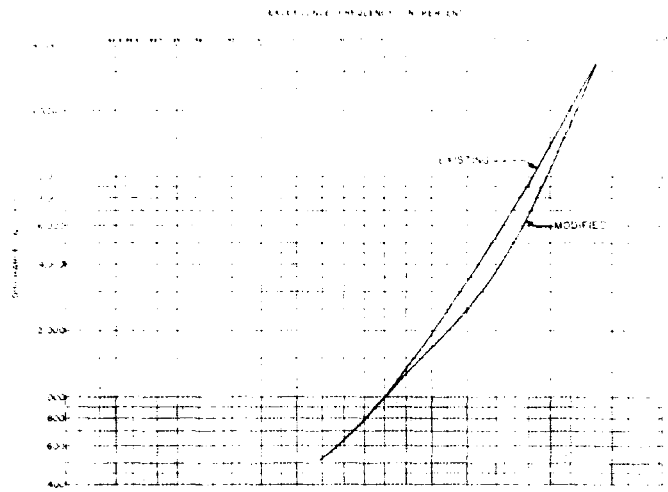
DEPARTMENT OF THE ARMY
ST PAUL DISTRICT CORPS OF ENGINEERS
ST PAUL, MINNESOTA

DESIGN MEMORANDUM NO 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
DISCHARGE FREQUENCY CURVES
SOURIS RIVER AND TRIBUTARIES
NATURAL AND EXISTING CONDITIONS

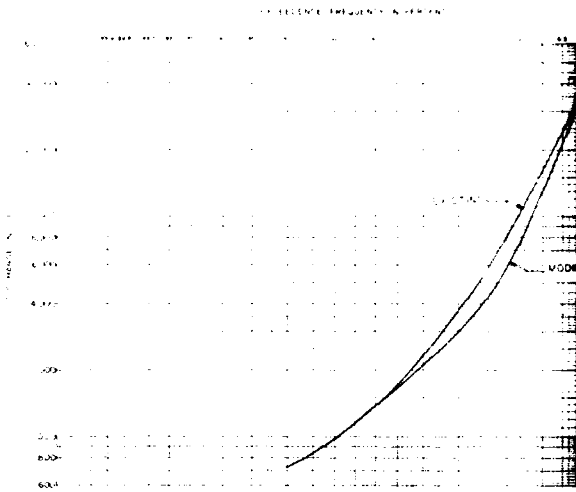
SUBMITTED BY
APPROVED
DATE JUNE 1983
SCALE AS SHOWN
DRAWING NUMBER RI-R-5/754
SHEET OF

PLATE A-5

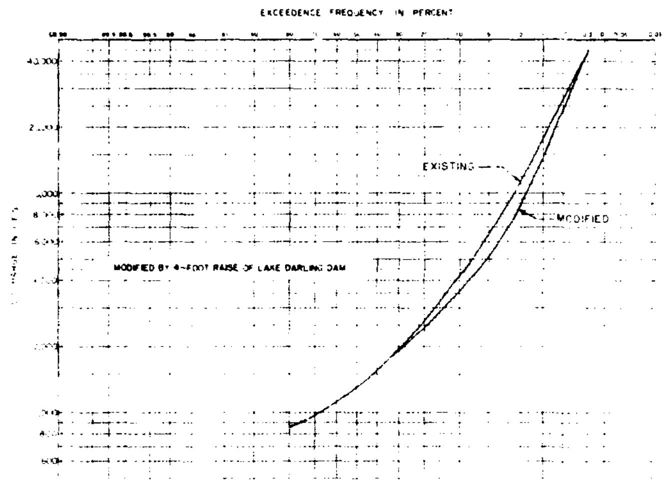
1 2



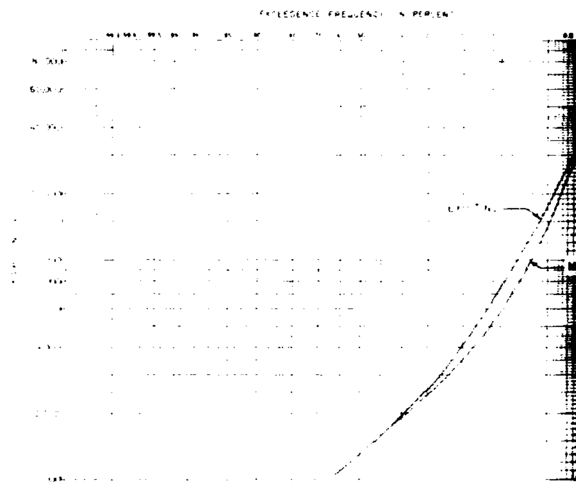
DISCHARGE FREQUENCY CURVES
SOURIS RIVER NEAR FOXHOLM, N.D.



DISCHARGE FREQUENCY CURVES
SOURIS RIVER AT MINOT, N.D.

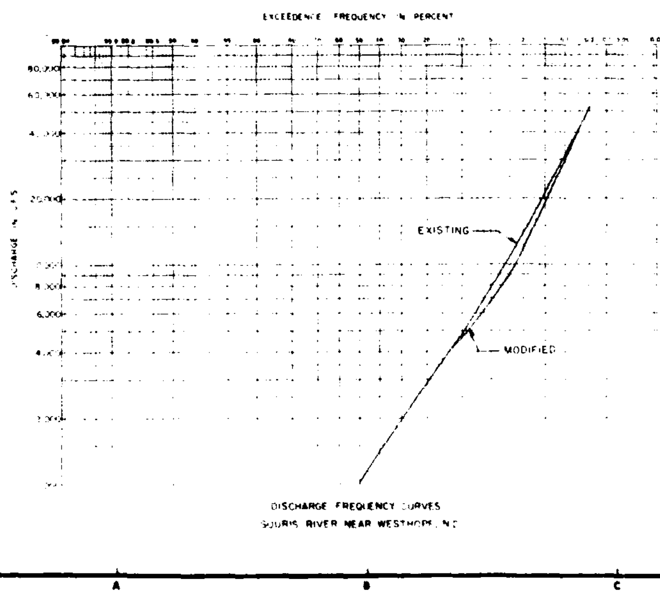


DISCHARGE FREQUENCY CURVES
SOURIS RIVER AT VELVA

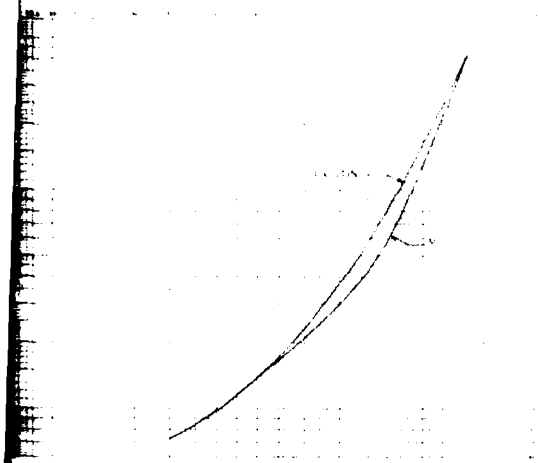


DISCHARGE FREQUENCY CURVES
SOURIS RIVER NEAR VERENDRYE, N.D.

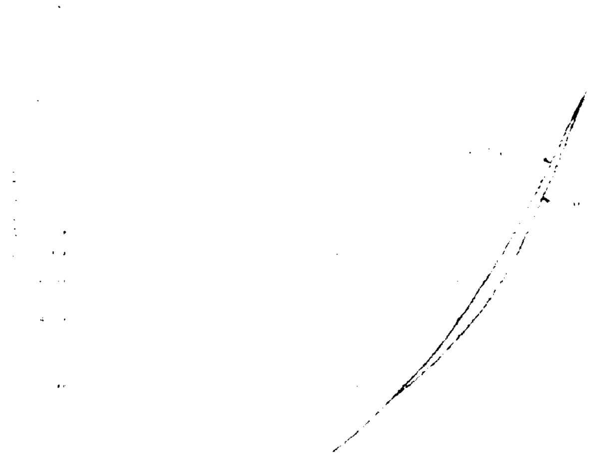
NOTE
PARTIAL DURATION INSTANTANEOUS PEAKS
EXCEPT WESTHOPE - ANNUAL MEAN DAILY PEAKS



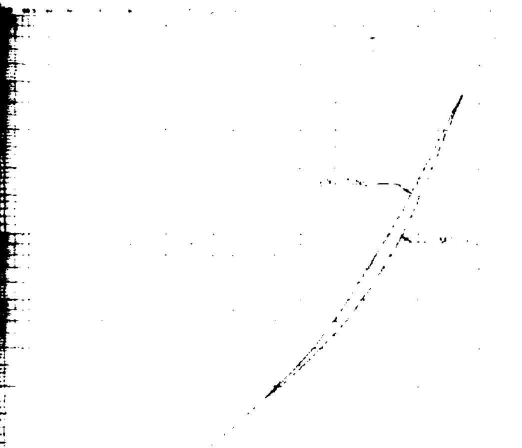
DISCHARGE FREQUENCY CURVES
SOURIS RIVER NEAR WESTHOPE, N.D.



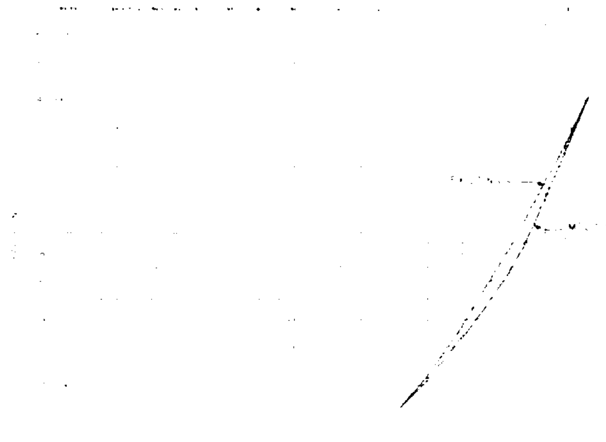
DISCHARGE FREQUENCY CURVES
SOURIS RIVER AT MINOT, N.D.



DISCHARGE FREQUENCY CURVES
SOURIS RIVER AT SAWYER, N.D.



DISCHARGE FREQUENCY CURVES
SOURIS RIVER NEAR VERENDRYE, N.D.



DISCHARGE FREQUENCY CURVES
SOURIS RIVER NEAR BANTRY, N.D.

NOTE
PARTIAL DURATION INSTANTANEOUS PEAKS
EXCEPT WESTHOPE ANNUAL MEAN DAILY PEAKS

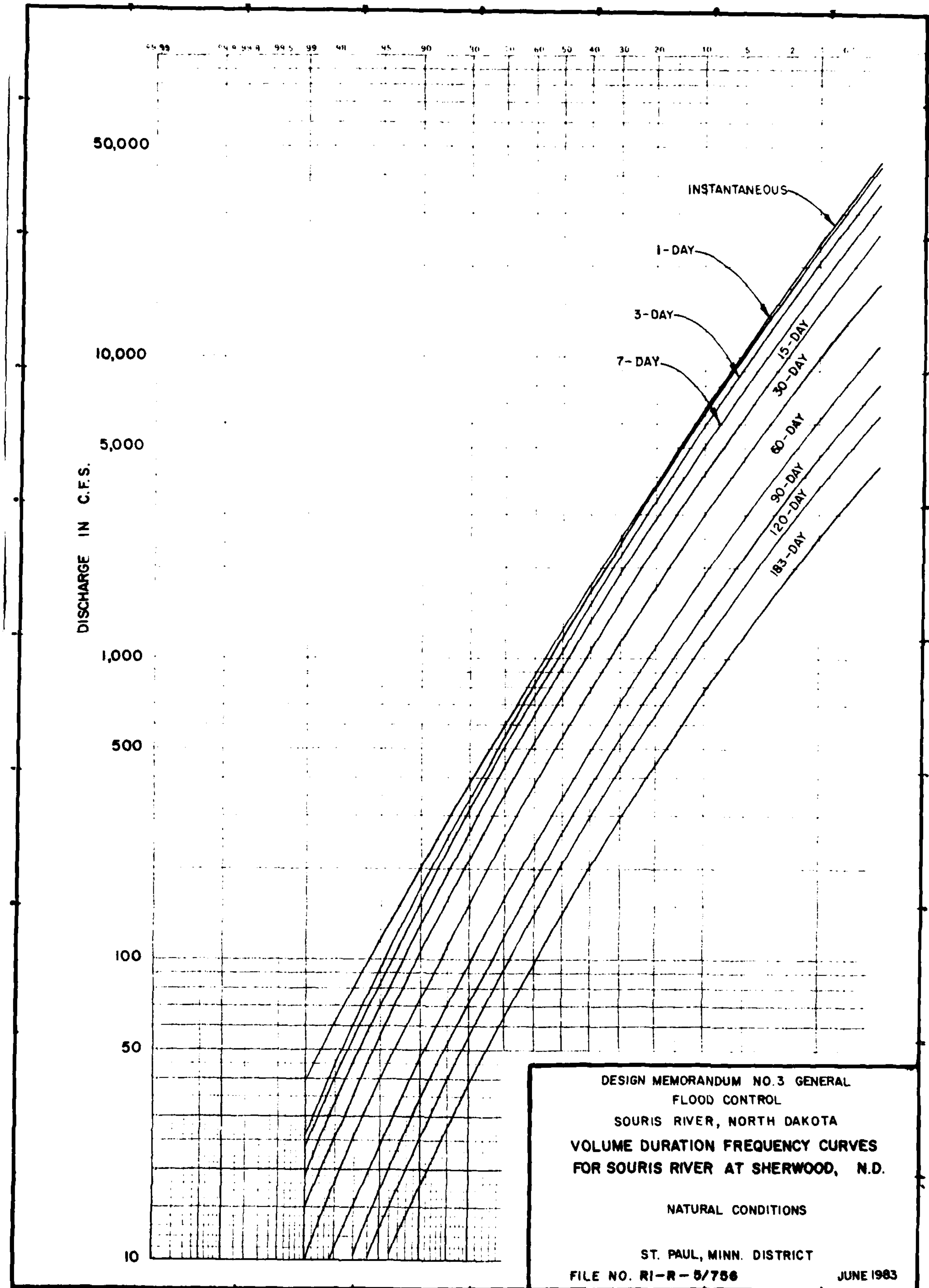
SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGN MEMORANDUM NO. 1 — GENERAL
FLOOD CONTROL — LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
DISCHARGE FREQUENCY CURVES
SOURIS RIVER
EXISTING AND MODIFIED CONDITIONS

DESIGNED BY
DRAWN BY
CHECKED BY
SUBMITTED BY
APPROVED
DATE
DRAWING NUMBER
755
SHEET OF

PLATE 6



DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL
SOURIS RIVER, NORTH DAKOTA

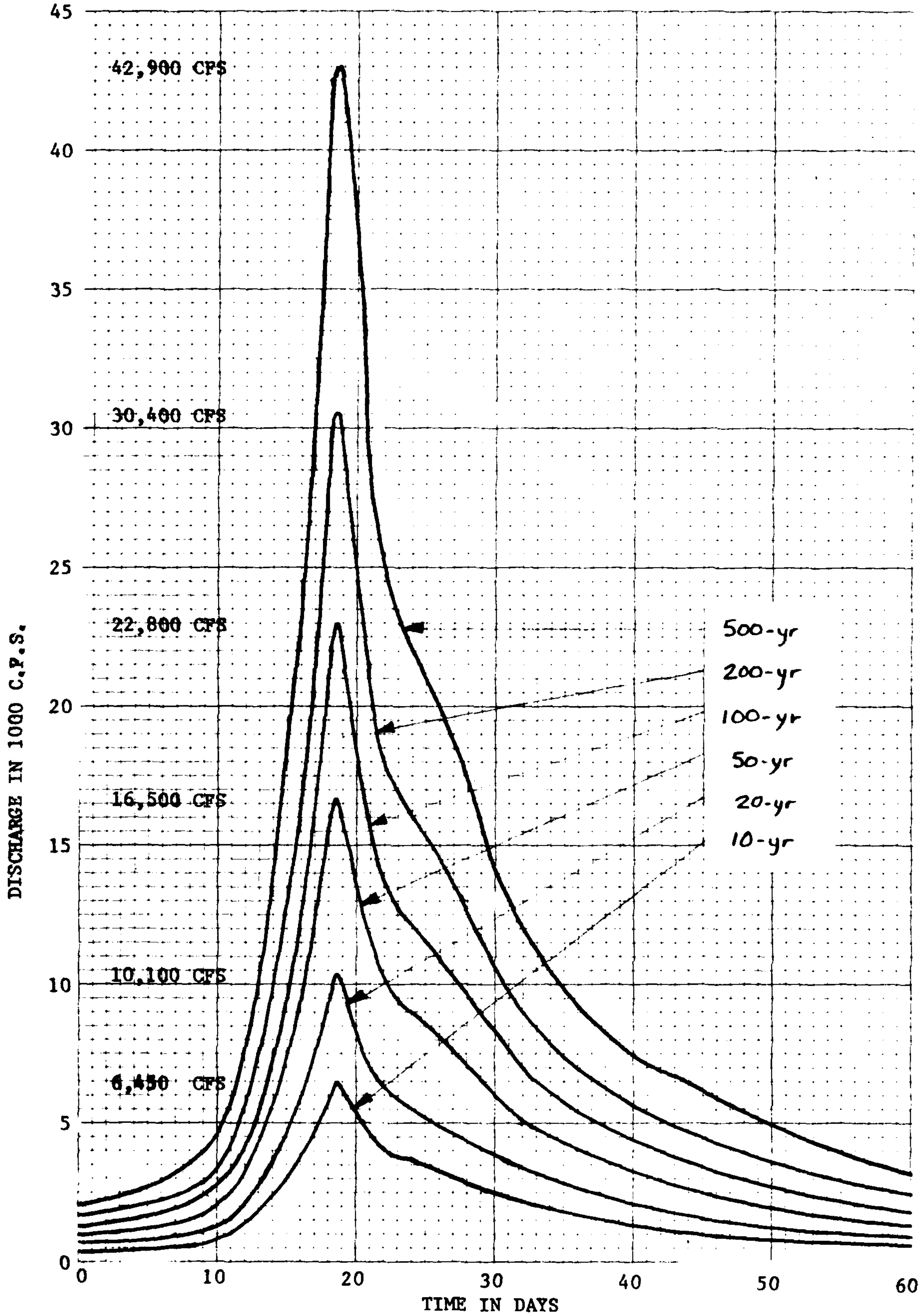
VOLUME DURATION FREQUENCY CURVES FOR SOURIS RIVER AT SHERWOOD, N.D.

NATURAL CONDITIONS

ST. PAUL, MINN. DISTRICT

FILE NO. RI-R-5/756 JUNE 1983

PLATE A-7

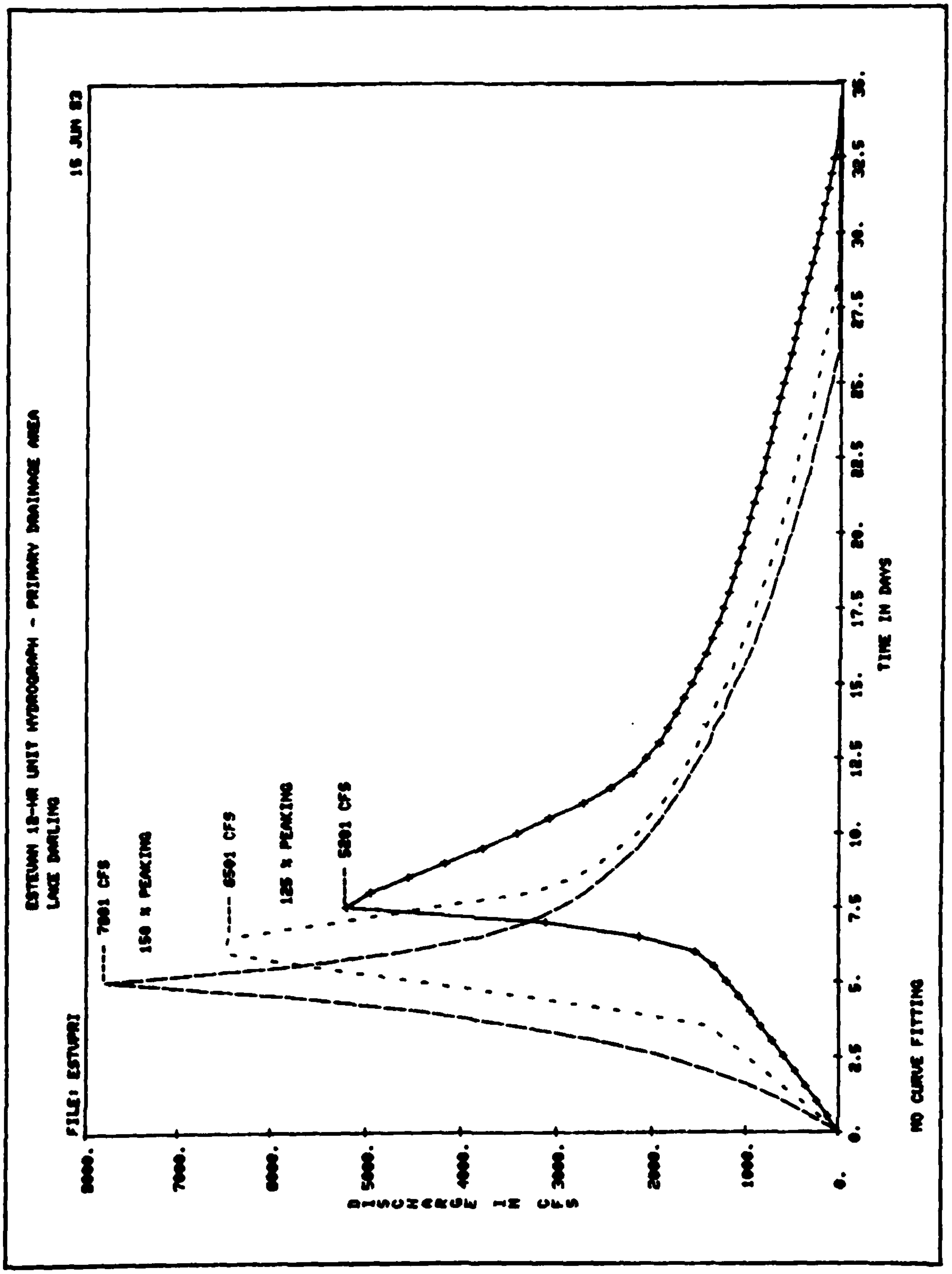


DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - SOURIS RIVER

SYNTHETIC HYDROGRAPHS NEAR SHERWOOD, ND

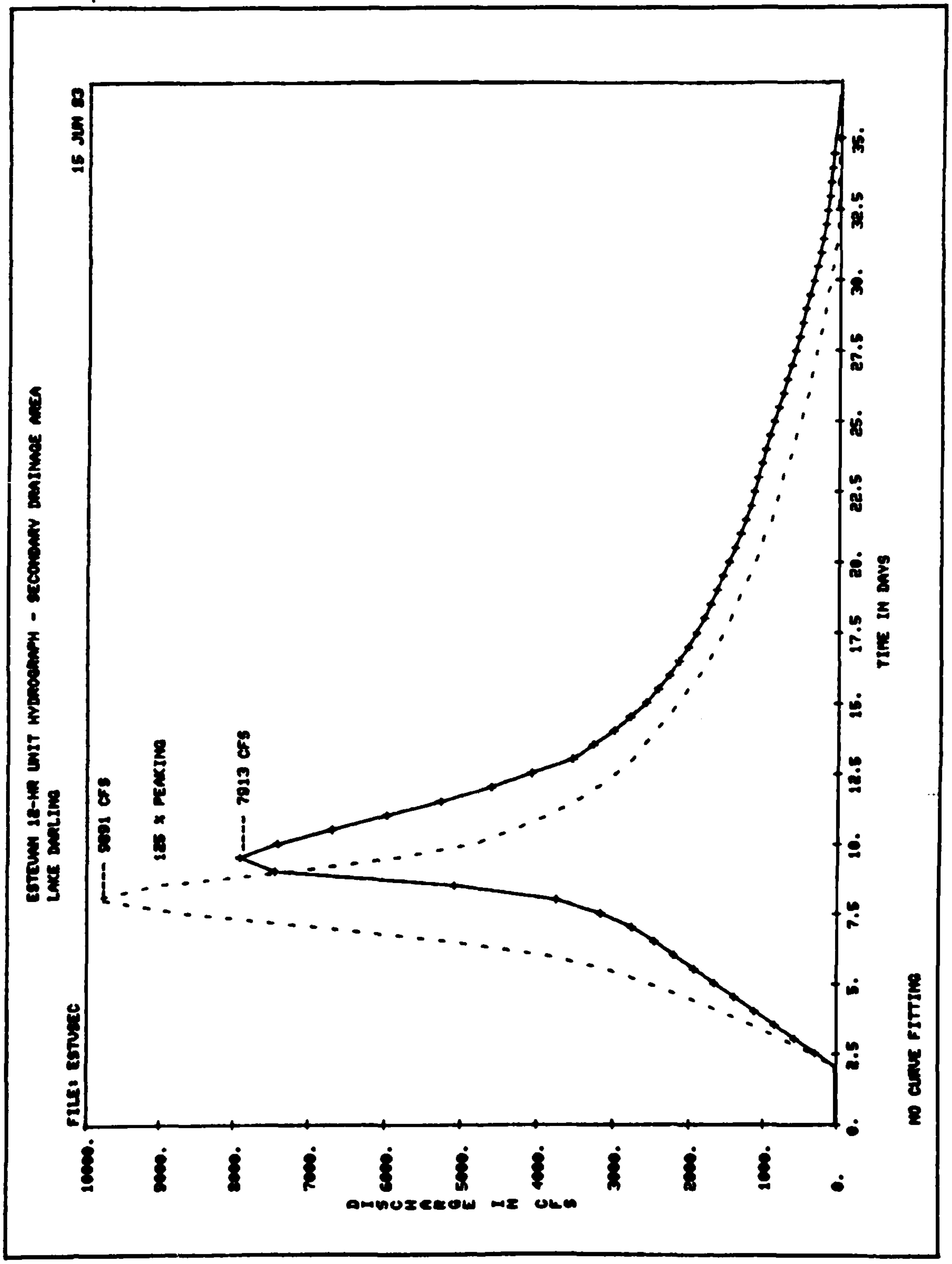
FILE NO. R-R1-5/757 ST. PAUL DISTRICT JUNE 1983

PLATE A-8

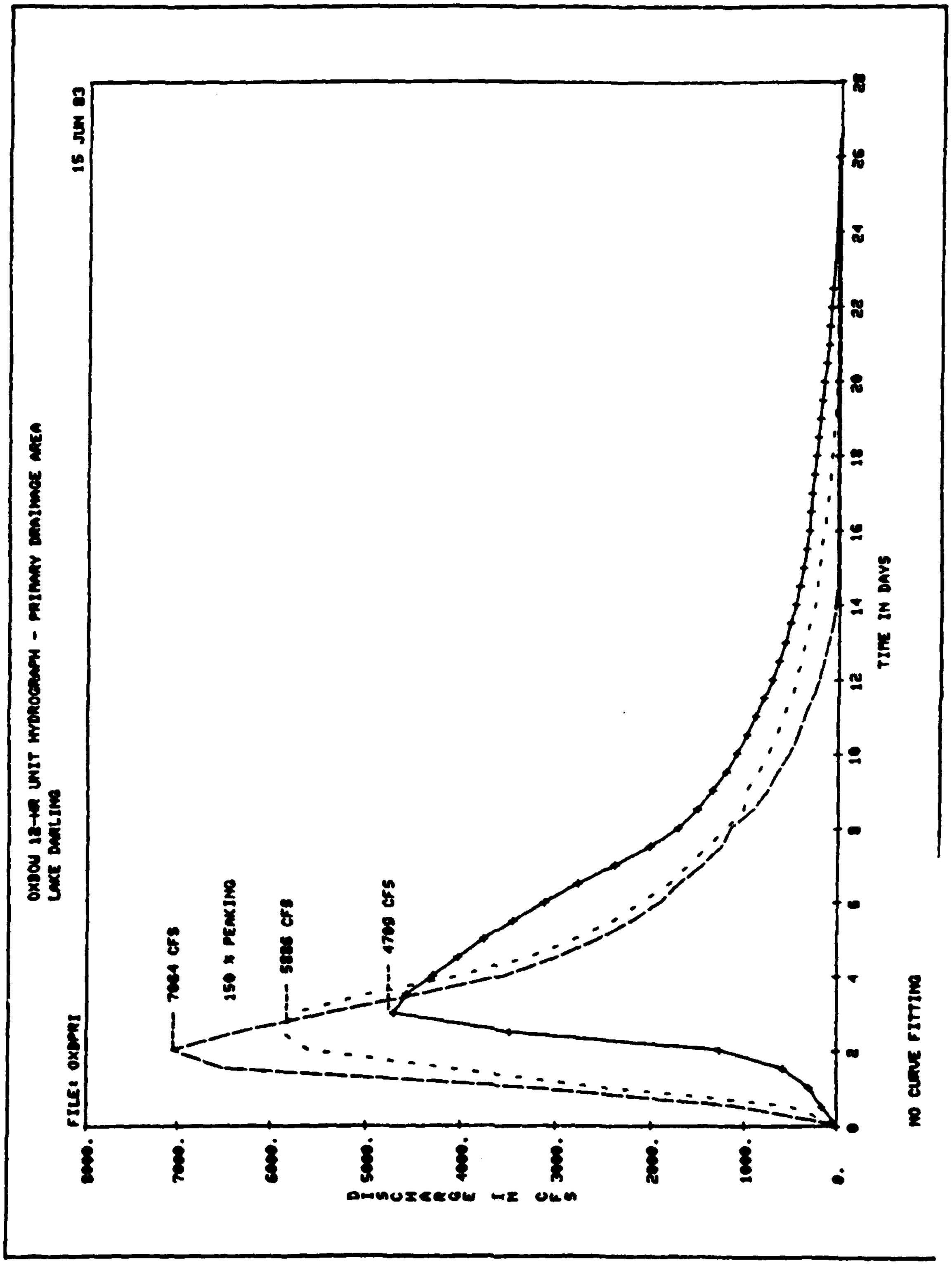


FILE NO. R-R1-5/758

PLATE A-9



ESTEVAN 18-HR UNIT HYDROGRAPH - SECONDARY DRAINAGE AREA
LAKE DARLING
FILE: ESTVSEC
15 JUN 83
9891 CFS
125 % PEAKING
7913 CFS
DISCHARGE IN CFS
0.
1000.
2000.
3000.
4000.
5000.
6000.
7000.
8000.
9000.
10000.
0.
2.5
5.
7.5
10.
12.5
15.
17.5
20.
22.5
25.
27.5
30.
32.5
35.
TIME IN DAYS
NO CURVE FITTING


OXBOW 12-HR UNIT HYDROGRAPH - PRIMARY DRAINAGE AREA
LAKE DARLING
15 JUN 83
FILE: OXBPRI
7064 CFS
150 % PEAKING
5886 CFS
4709 CFS
DISCHARGE IN CFS
8000.
7000.
6000.
5000.
4000.
3000.
2000.
1000.
0.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
TIME IN DAYS
NO CURVE FITTING

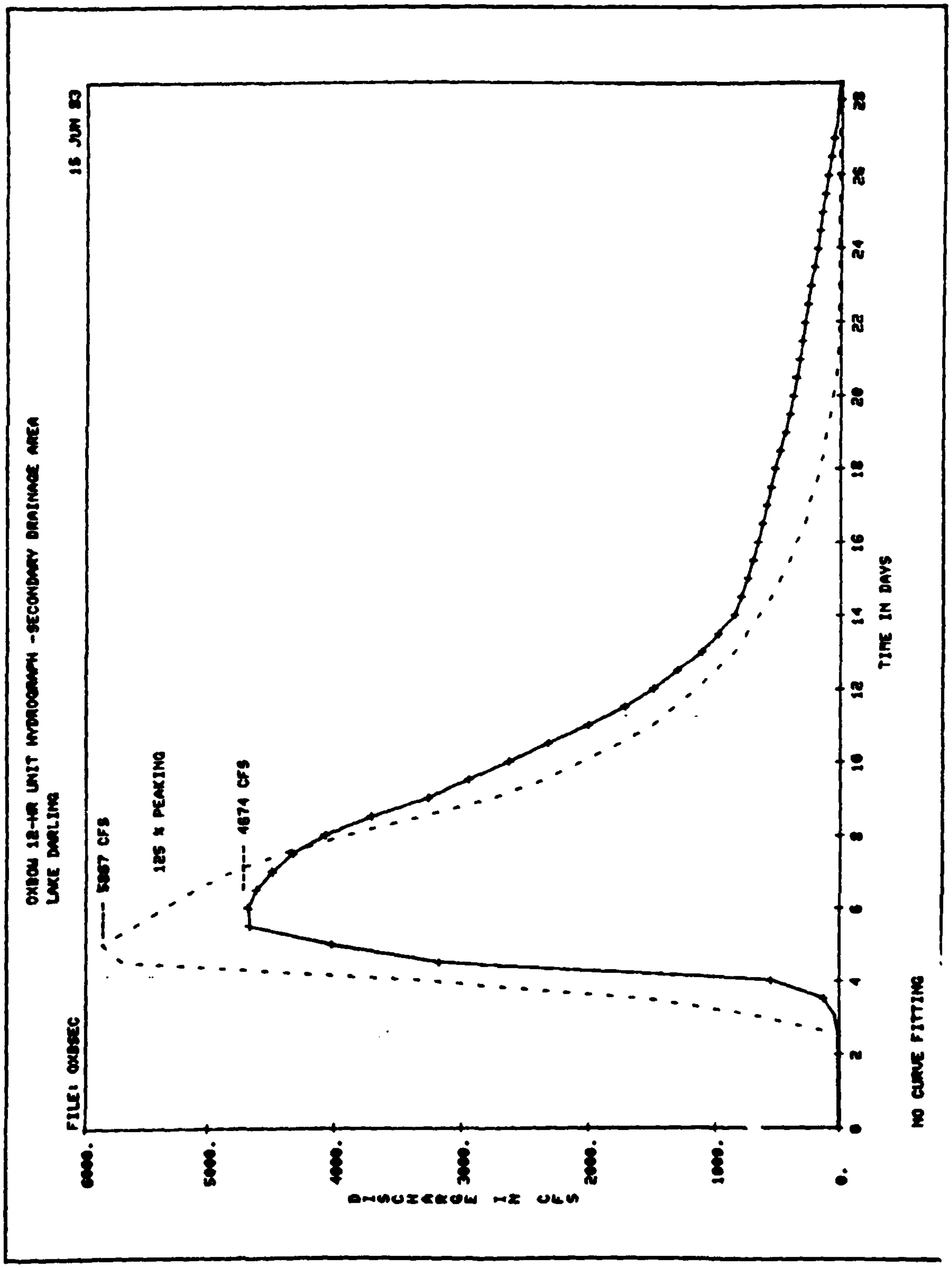
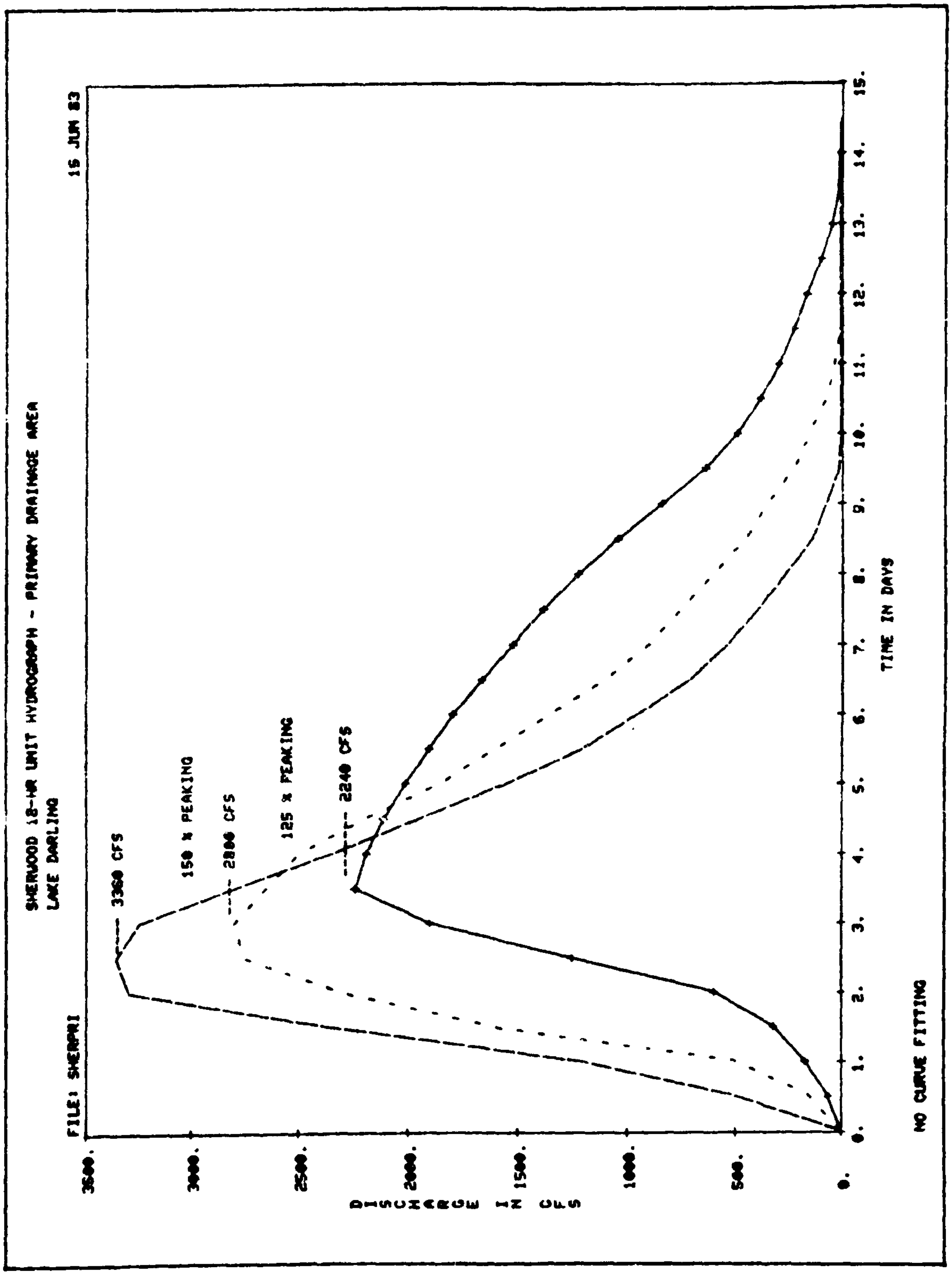


PLATE A-12

FILE NO. R-R1-5/761



FILE NO. R-R1-5/762 **PLATE A-13**

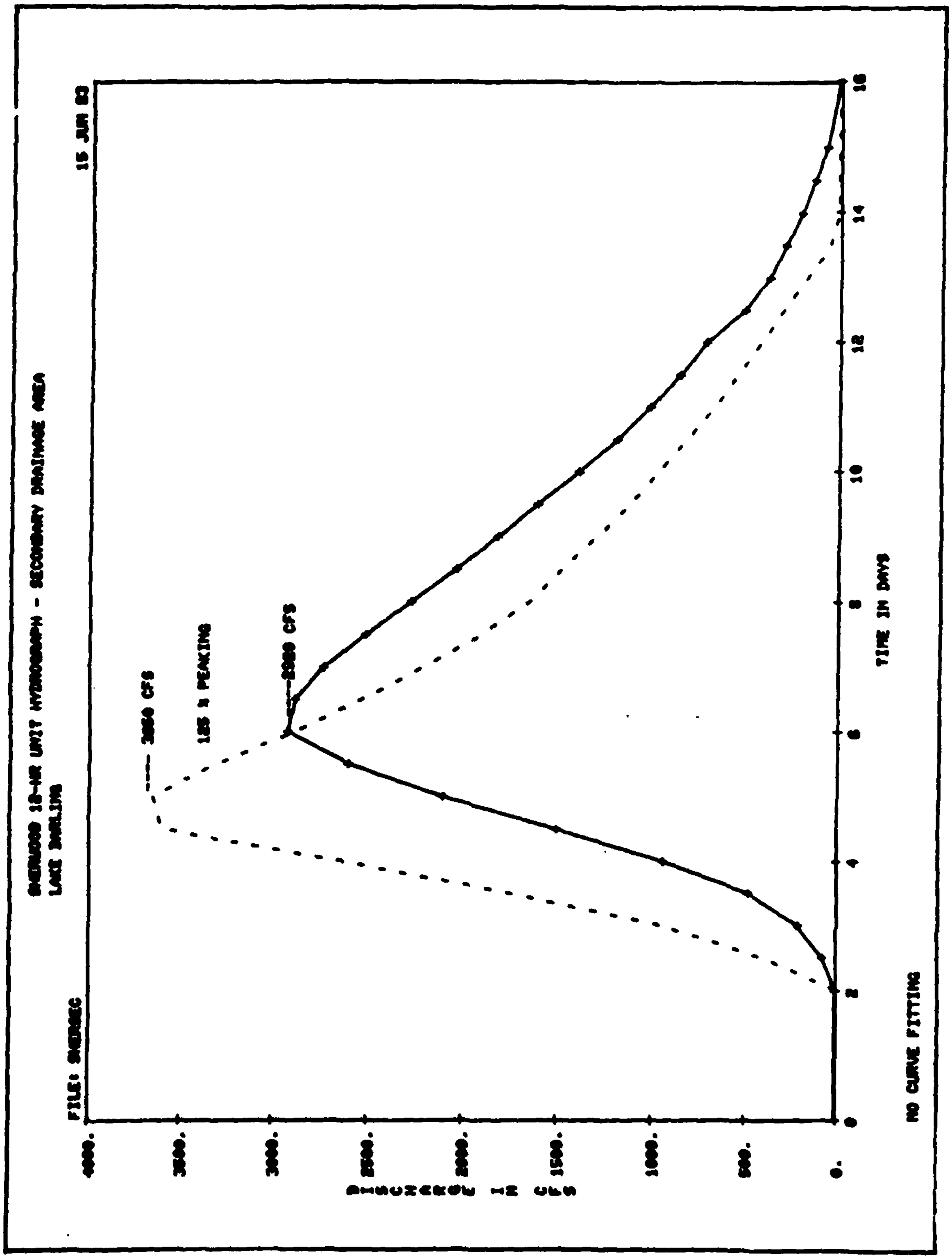
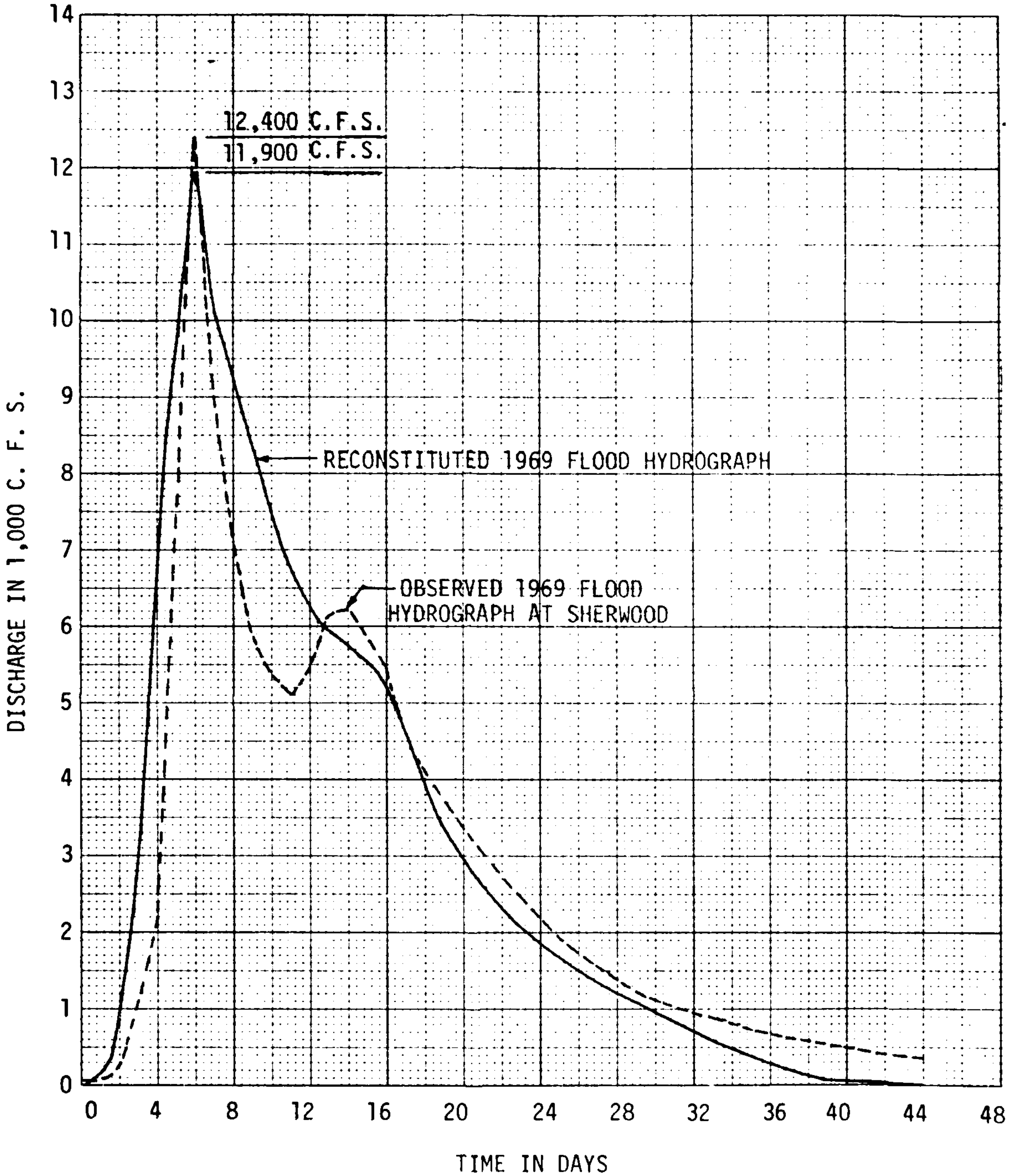


PLATE A-14

FILE NO. R-R1-5/763



DESIGN MEMORANDUM NO 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

SOURIS RIVER BASIN ABOVE SHERWOOD
RECONSTITUTION OF THE 1969 HYDROGRAPH

St. Paul, Minn. District

FILE NO. RI-R-5/764 JUNE 1983

PLATE A-15

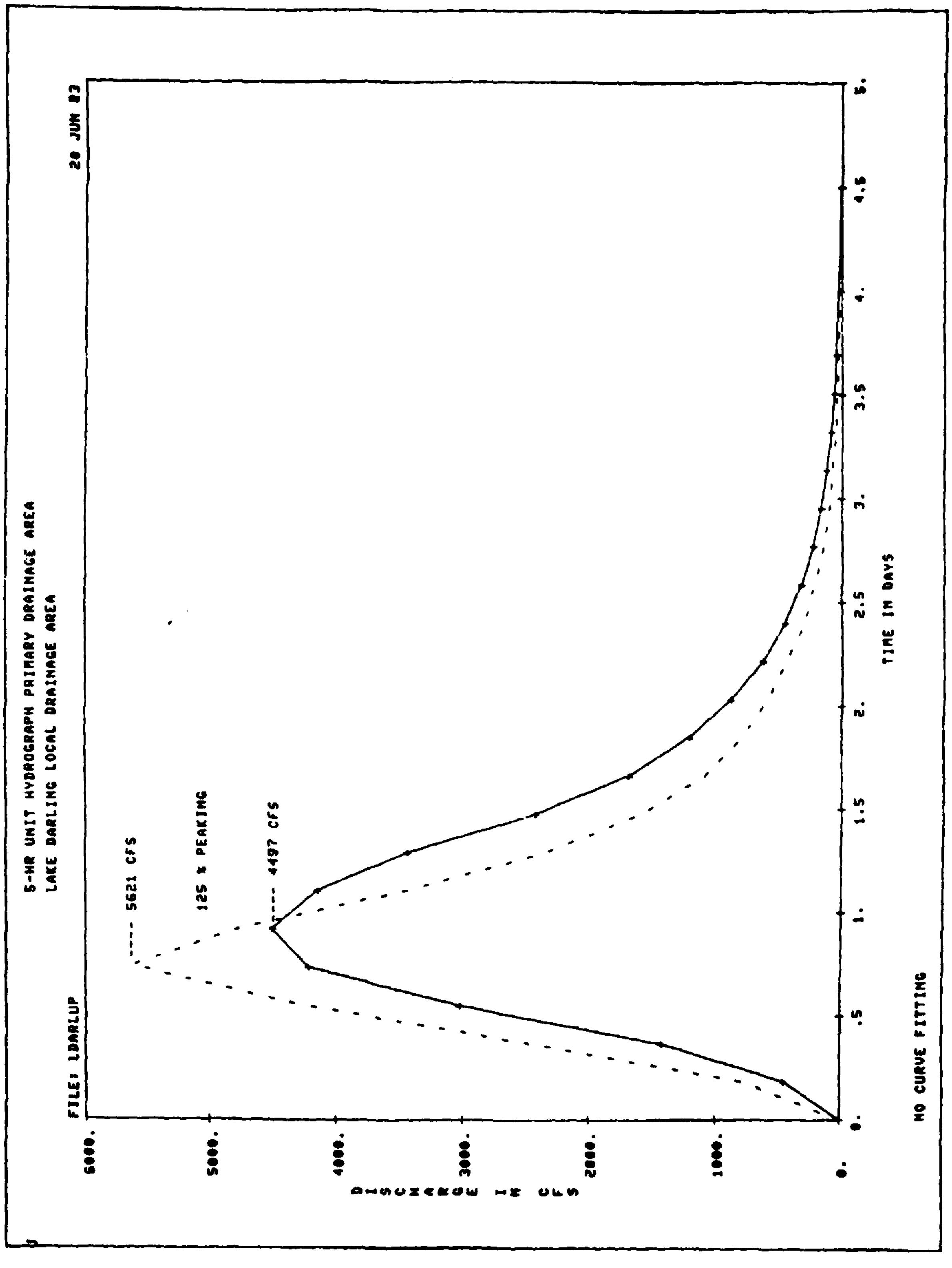


PLATE A-16

FILE NO. R-R1-5/765

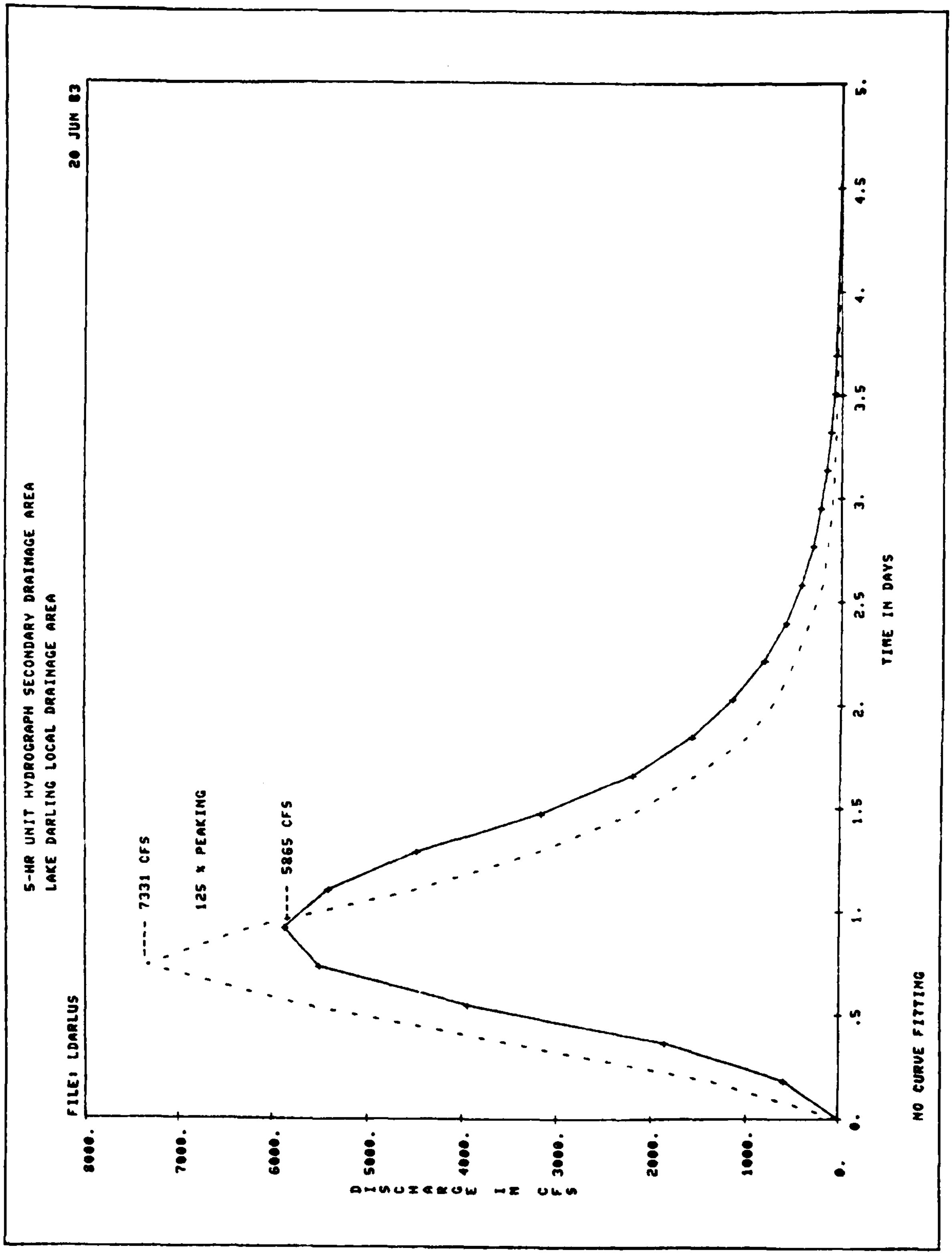


PLATE A-17

FILE NO. R-R1-5/766

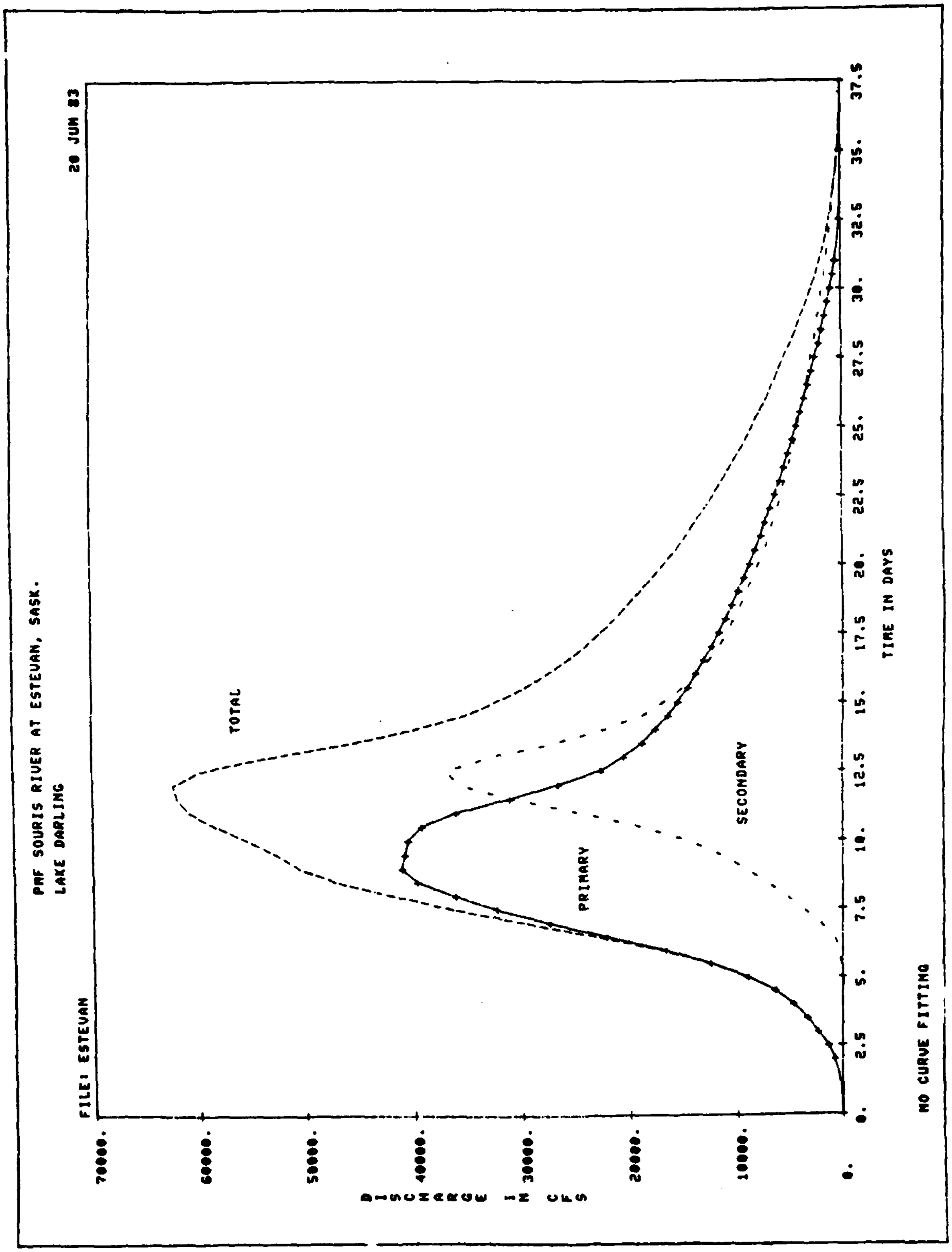
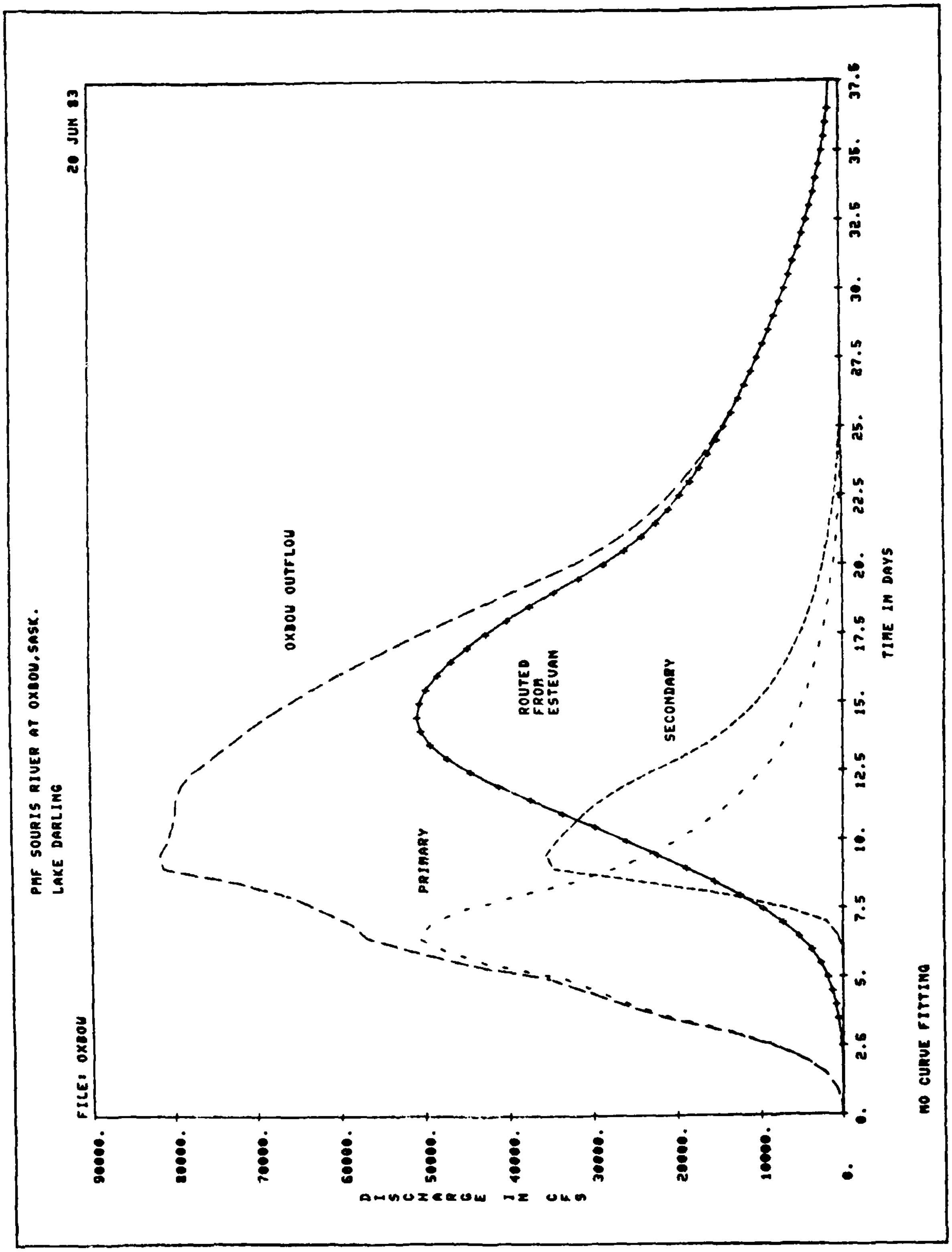


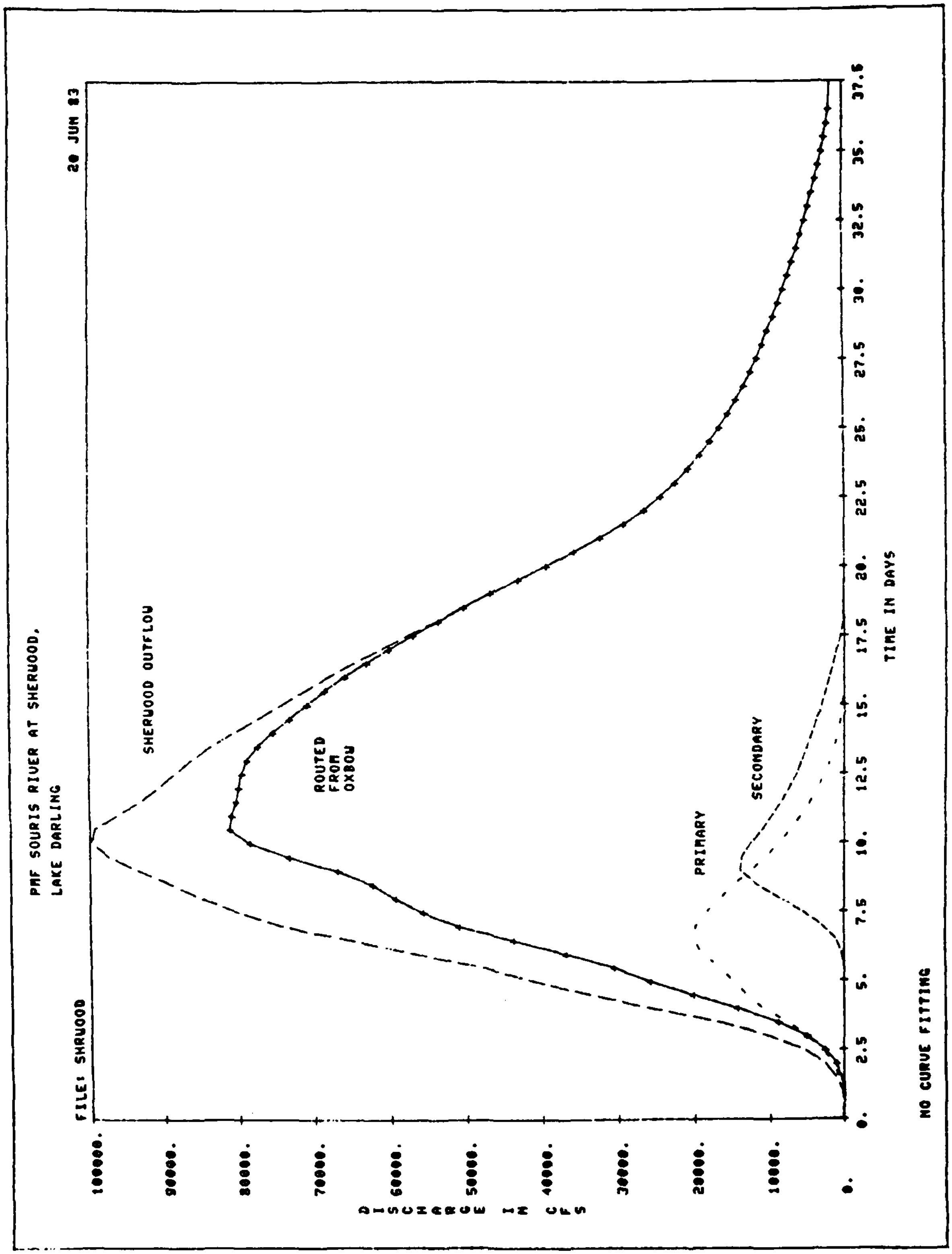
PLATE A-18

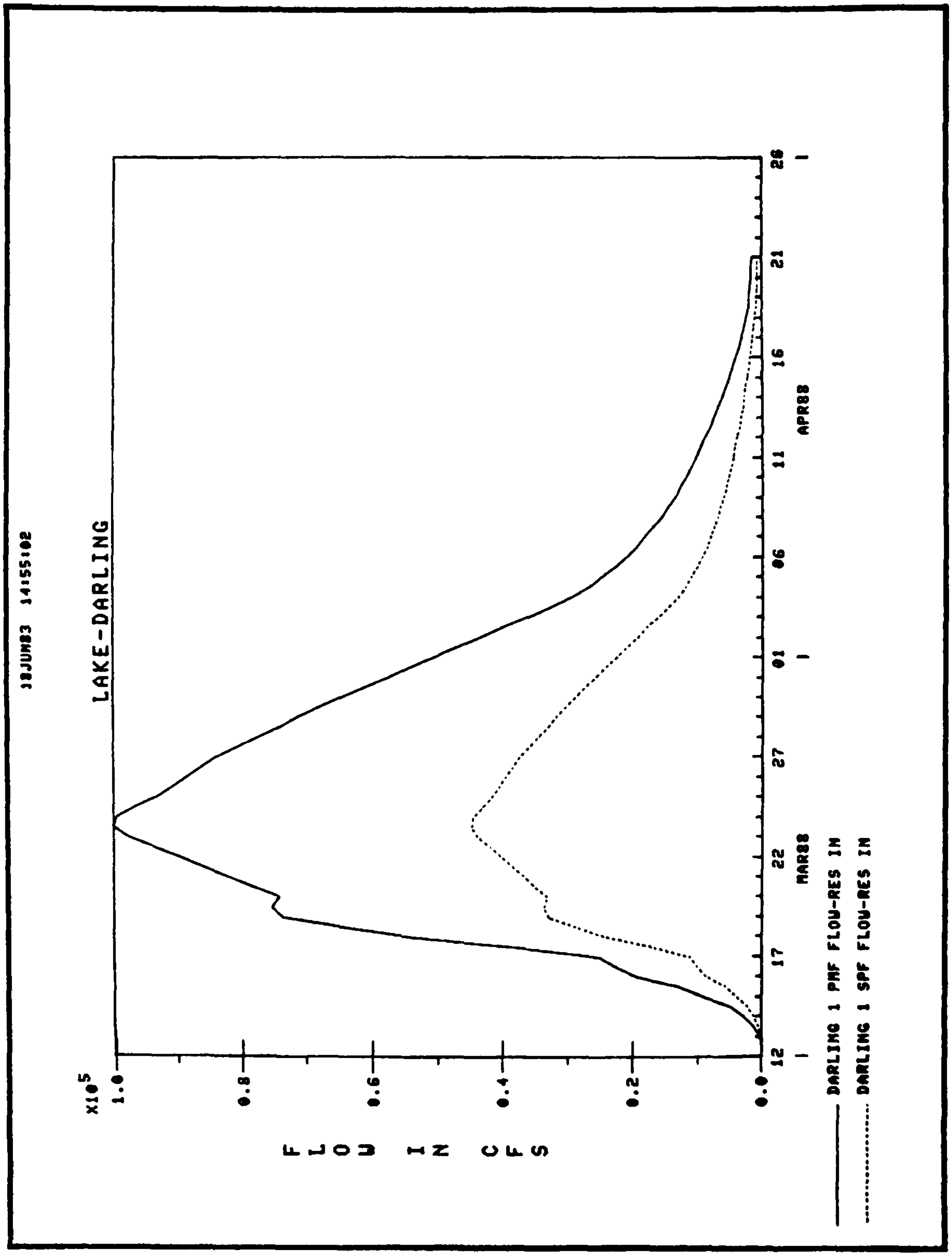
FILE NO. R-R1-5/767



FILE NO. R-R1-5/768

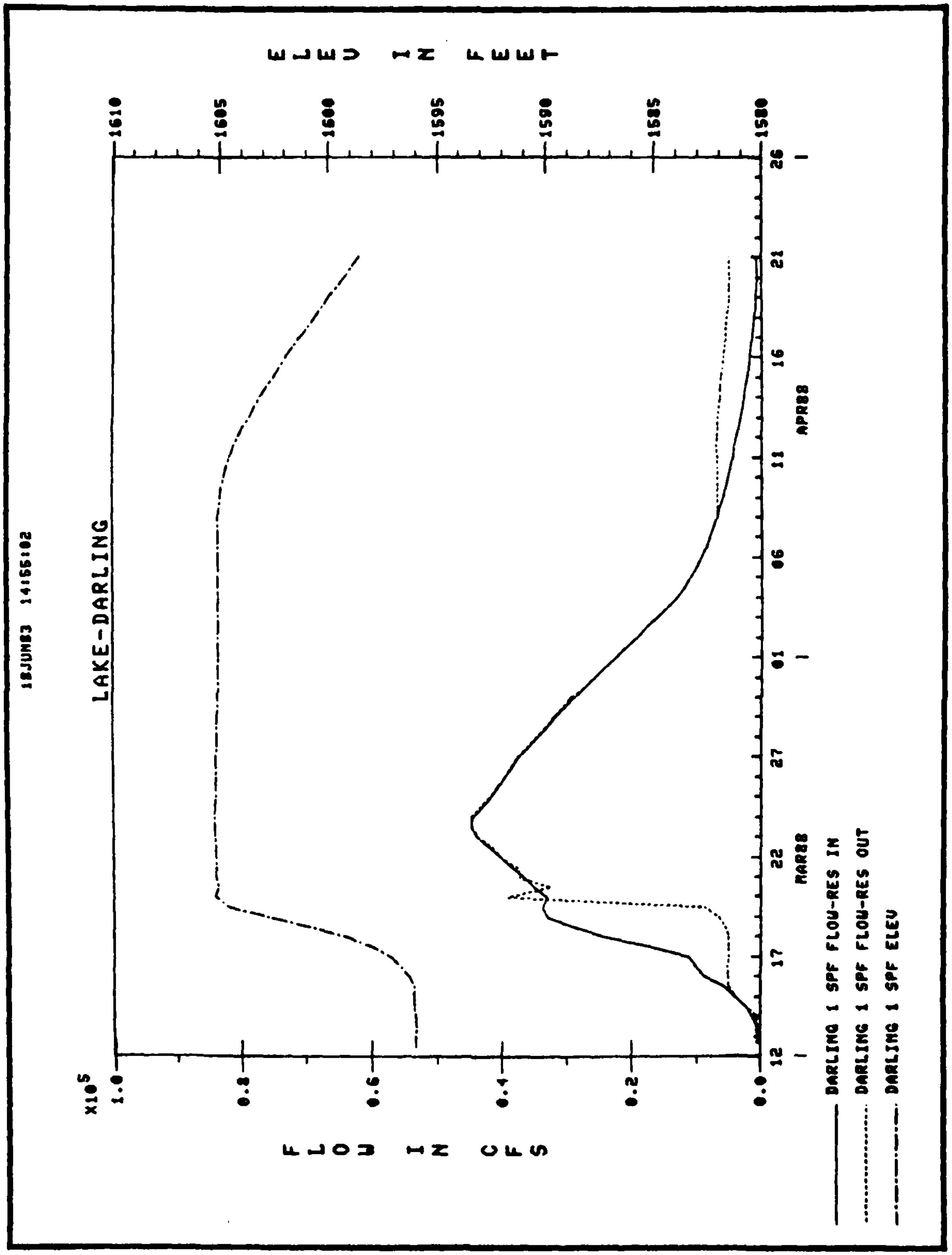
PLATE A-19


PMF SOURIS RIVER AT SHERWOOD,
LAKE DARLING
20 JUN 83
FILE: SHRWOOD
SHERWOOD OUTFLOW
ROUTED
FROM
OXBOW
PRIMARY
SECONDARY
DISCHARGE IN CFS
0.
10000.
20000.
30000.
40000.
50000.
60000.
70000.
80000.
90000.
100000.
TIME IN DAYS
0.
2.5
5.
7.5
10.
12.5
15.
17.5
20.
22.5
25.
27.5
30.
32.5
35.
37.5
NO CURVE FITTING

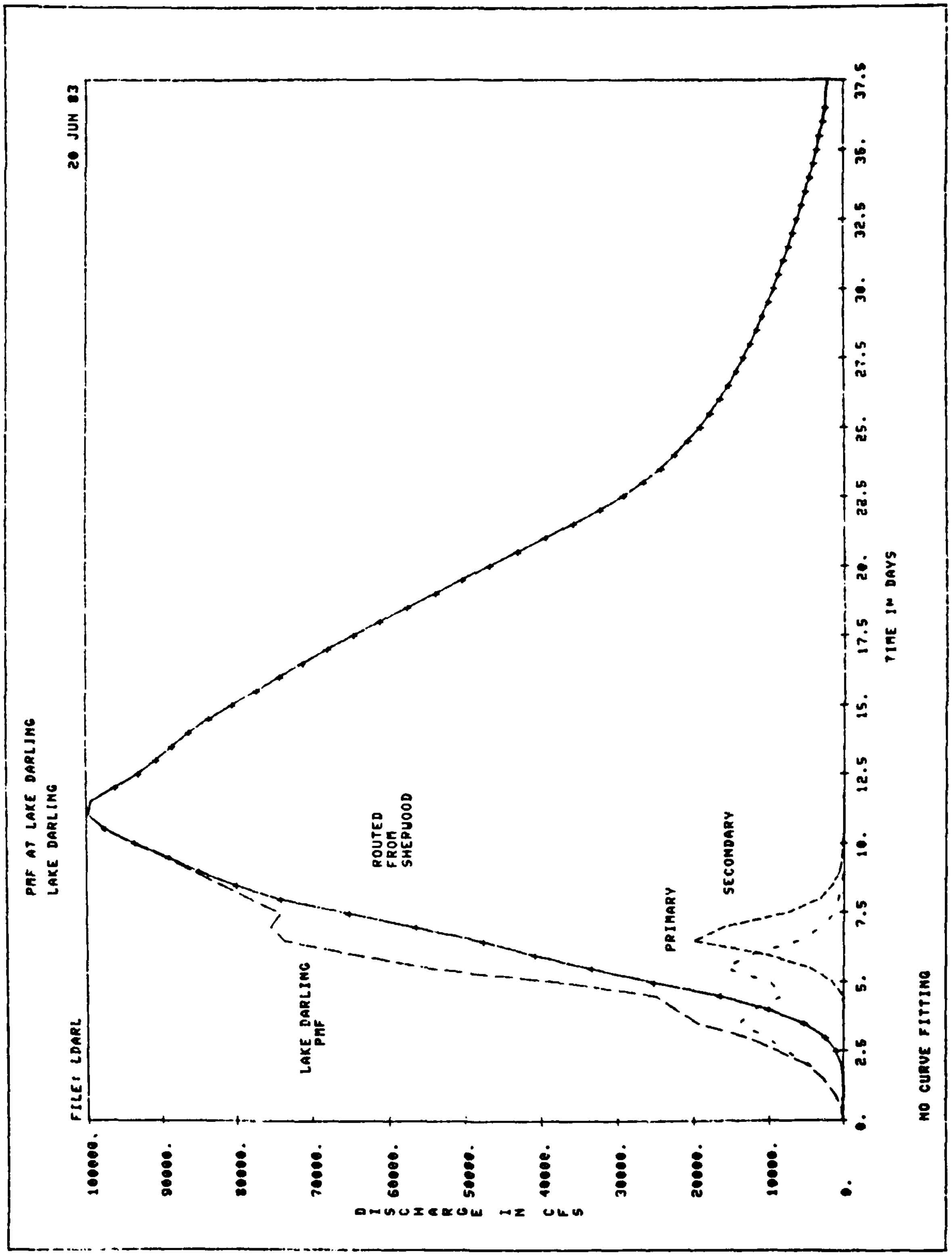


FILE NO. R-R1-5/770

PLATE A-21

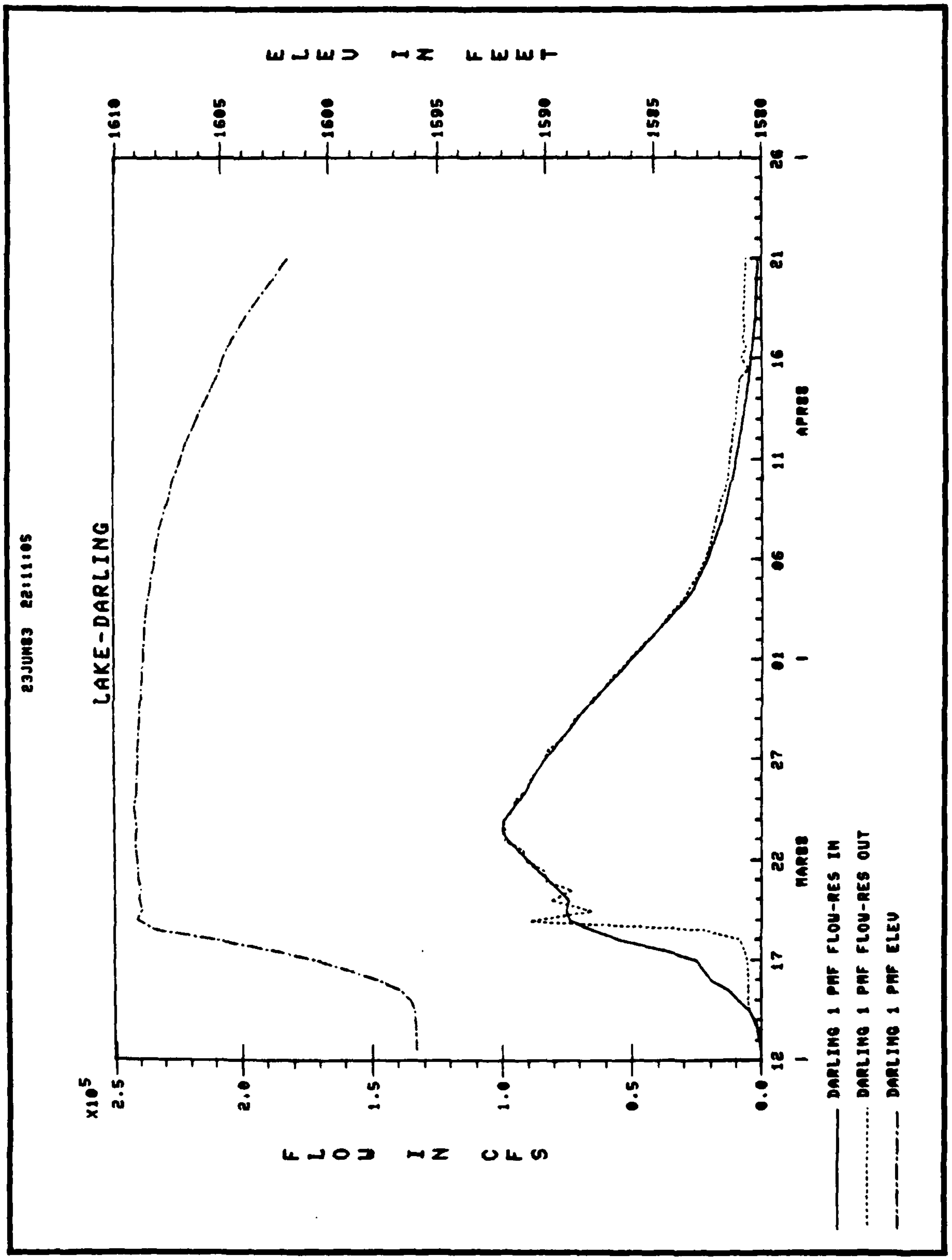


18JUN83 14:55:02
LAKE-DARLING
ELEV IN FEET
1610
1605
1600
1595
1590
1585
1580
FLOW IN CFS
X10^5
1.0
0.8
0.6
0.4
0.2
0.0
12
17
22
27
01
06
11
16
21
26
MAR88
APR88
DARLING 1 SPF FLOW-RES IN
DARLING 1 SPF FLOW-RES OUT
DARLING 1 SPF ELEV



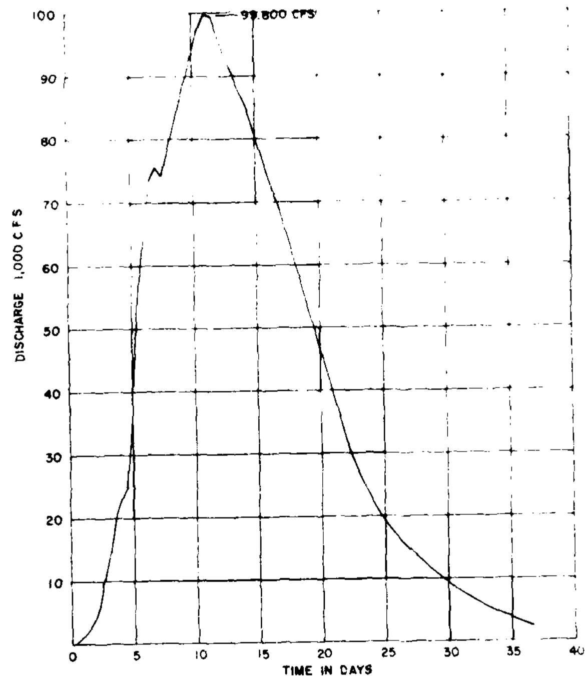
FILE NO. R-R1-5/772

PLATE A-23



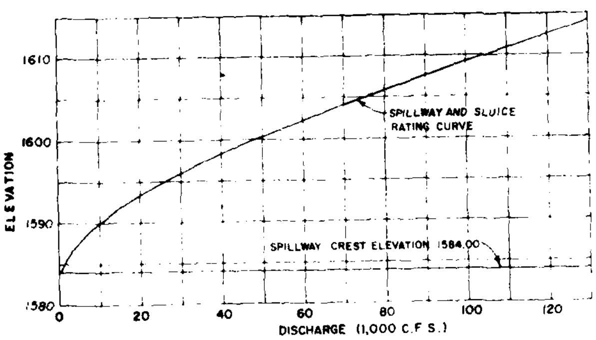
FILE NO. R-R1-5/773

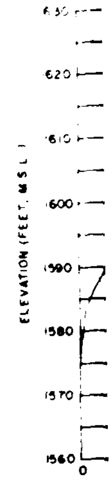
PLATE A-24

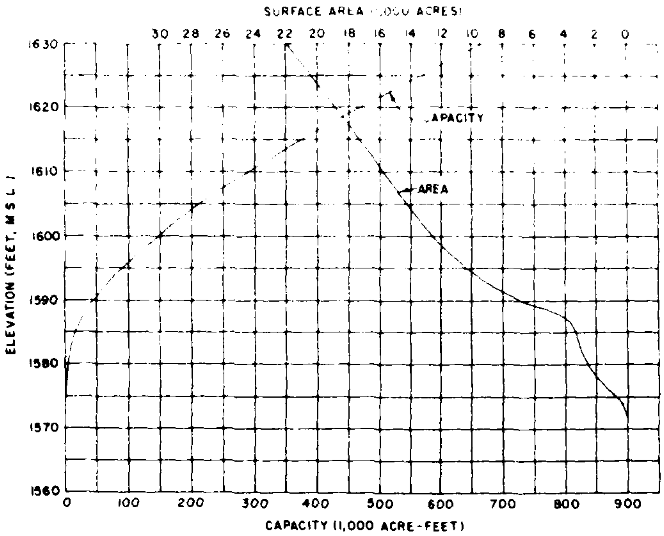


PROBABLE - MAXIMUM FLOOD

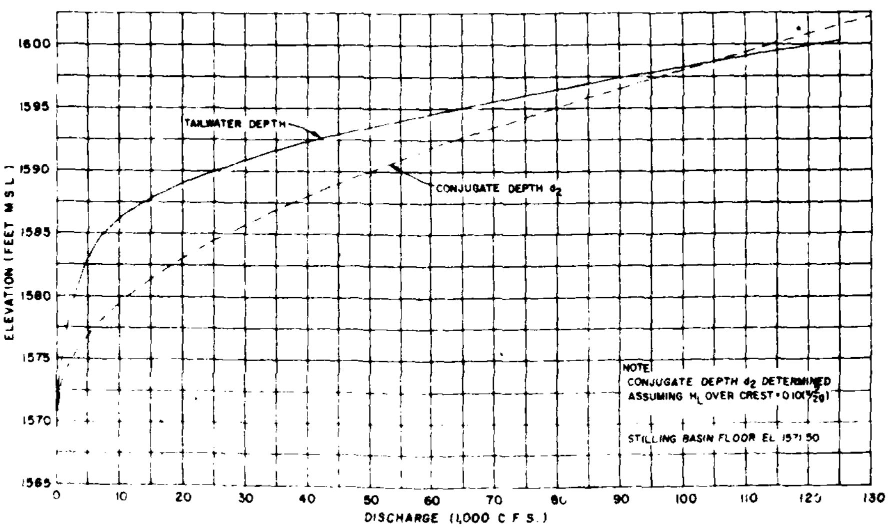
LAKE DARLING RESERVOIR







AREA-CAPACITY CURVES
LAKE DARLING RESERVOIR

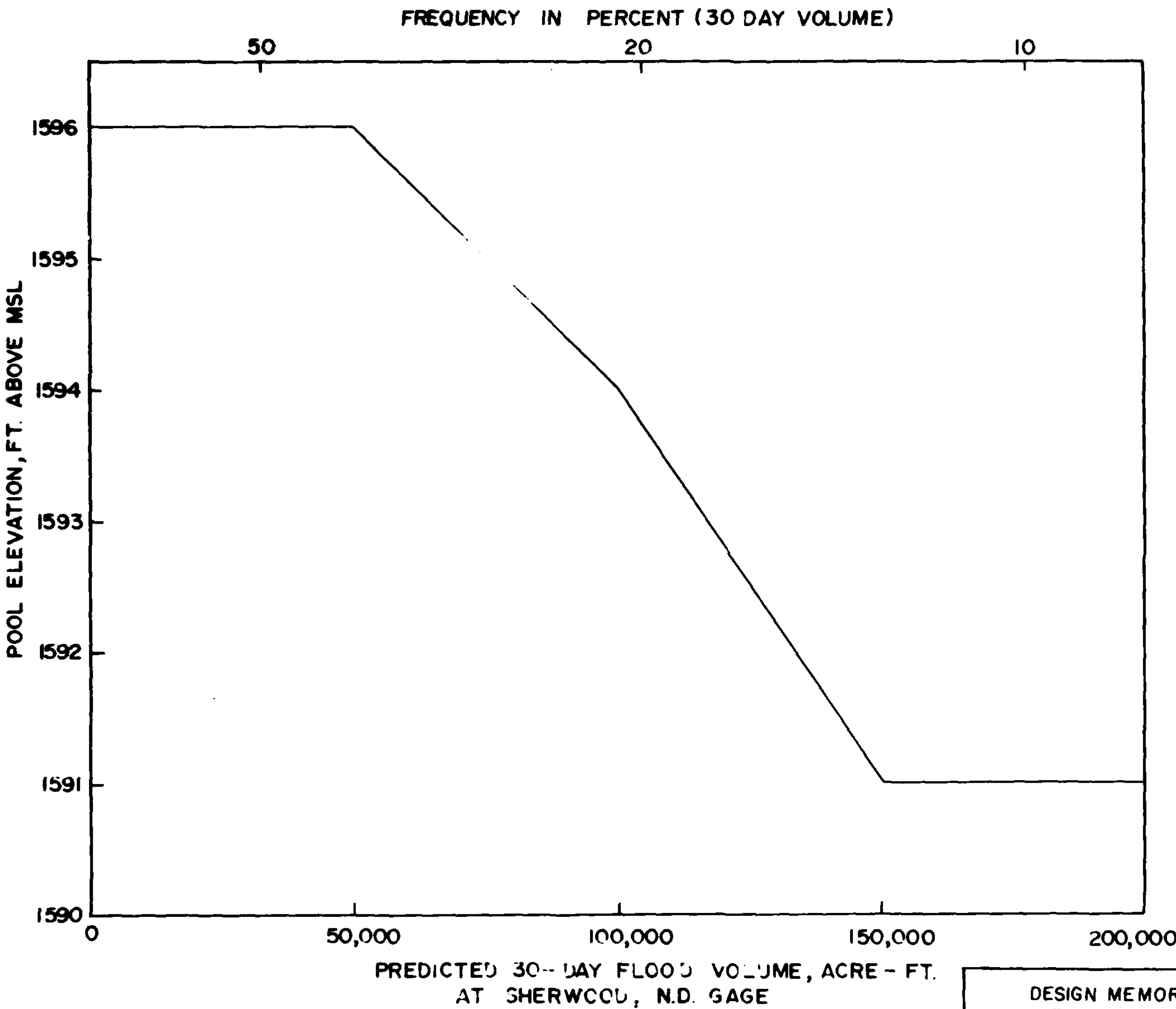


LAKE DARLING TAILWATER RATING CURVE
PROPOSED CONDITIONS

SAFETY PAYS

DESIGNED BY J R	DEPARTMENT OF THE ARMY ST PAUL DISTRICT CORPS OF ENGINEERS ST PAUL MINNESOTA
CHECKED BY J M	DESIGN MEMORANDUM NO 3 — GENERAL
PREPARED BY G M	FLOOD CONTROL - LAKE DARLING SOURIS RIVER, NORTH DAKOTA LAKE DARLING DAM HYDRAULIC DATA
SUBMITTED BY	DATE JUNE 1985
APPROVED	SCALE AS SHOWN
	DRAWING NUMBER RI-R-5/774
	SHEET OF

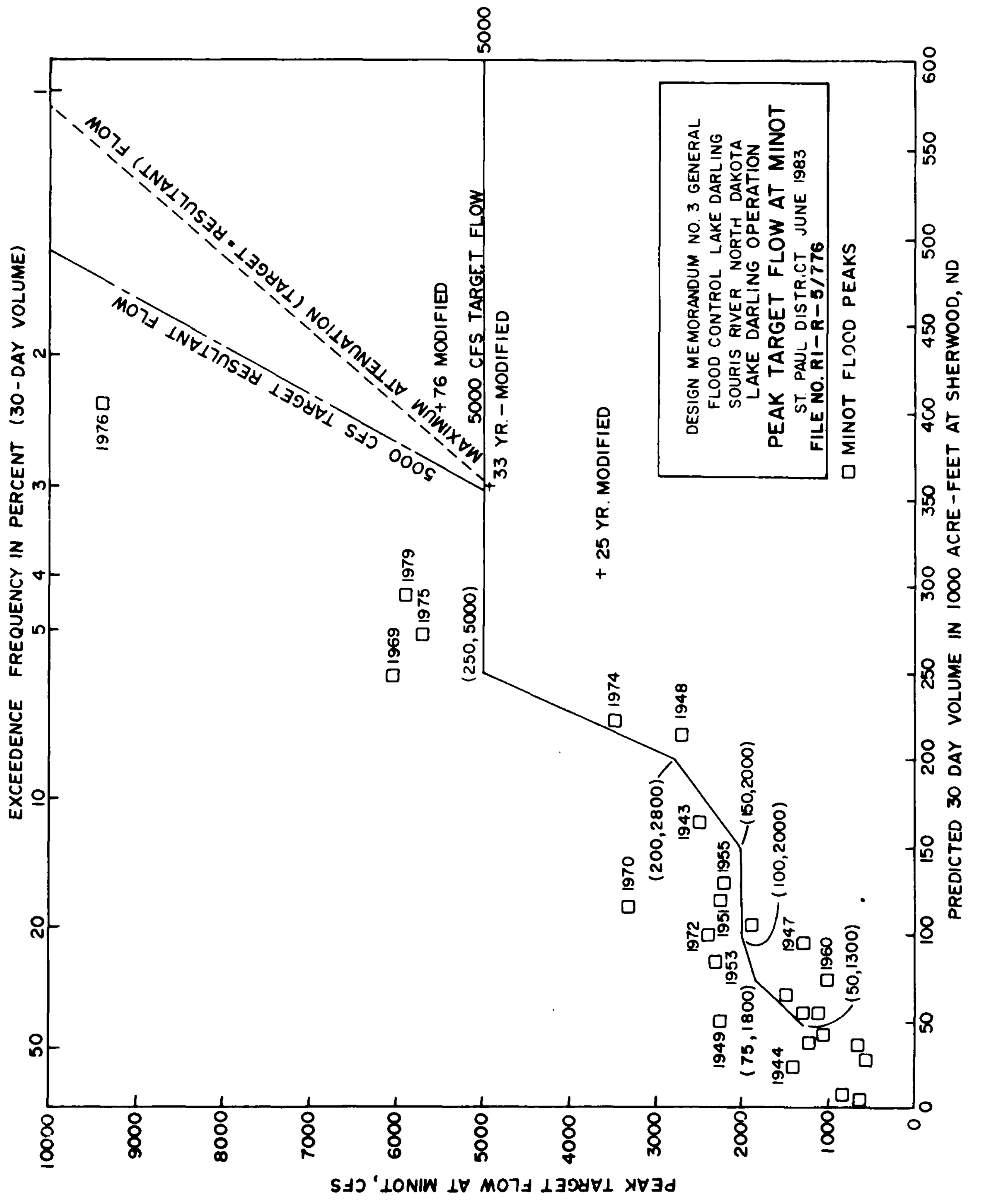
2



DESIGN MEMORANDUM NO 3 GENERAL
FLOOD CONTROL LAKE DARLING
SOURIS RIVER NORTH DAKOTA
LAKE DARLING-FLOOD CONTROL OPERATION

RESERVOIR TARGET DRAWDOWN LEVELS

ST. PAUL DISTRICT JUNE 1983
FILE NO. RI-R-5/776


DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL LAKE DARLING
SOURIS RIVER NORTH DAKOTA
LAKE DARLING OPERATION
PEAK TARGET FLOW AT MINOT
ST. PAUL DISTRICT JUNE 1983
FILE NO. RI-R-5/776
□ MINOT FLOOD PEAKS
EXCEEDENCE FREQUENCY IN PERCENT (30-DAY VOLUME)
PEAK TARGET FLOW AT MINOT, CFS
PREDICTED 30 DAY VOLUME IN 1000 ACRE-FEET AT SHERWOOD, ND
MAXIMUM ATTENUATION (TARGET = RESULTANT) FLOW
5000 CFS TARGET RESULTANT FLOW
5000 CFS TARGET FLOW
+76 MODIFIED
33 YR.-MODIFIED
+ 25 YR. MODIFIED
(250,5000)
(200,2800)
(150,2000)
(100,2000)
(75,1800)
(50,1300)
1976
1979
1975
1969
1974
1948
1943
1970
1955
1951
1972
1953
1947
1960
1949
1944
0
50
100
150
200
250
300
350
400
450
500
550
600
1000
2000
3000
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6000
7000
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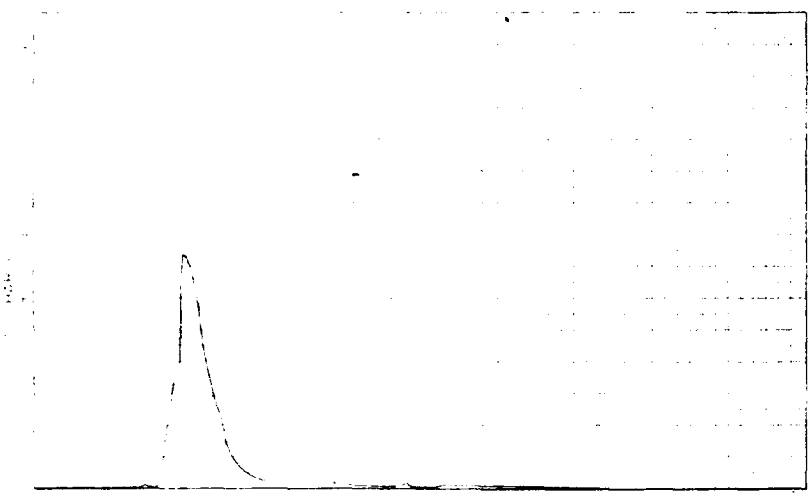
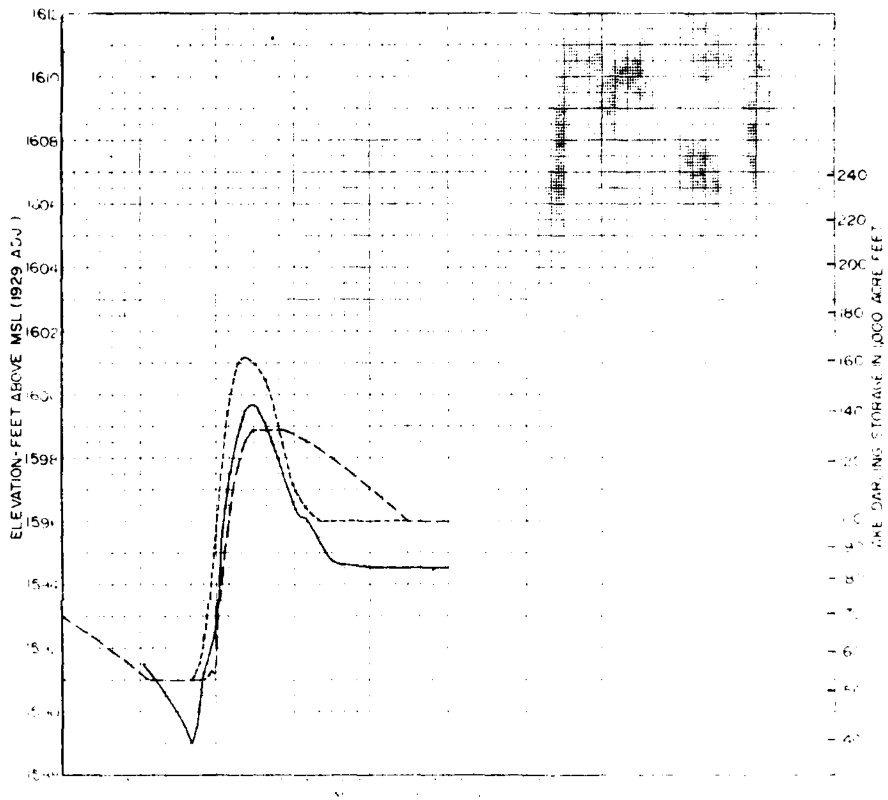
9000
10000
1
2
3
4
5
10
20
50

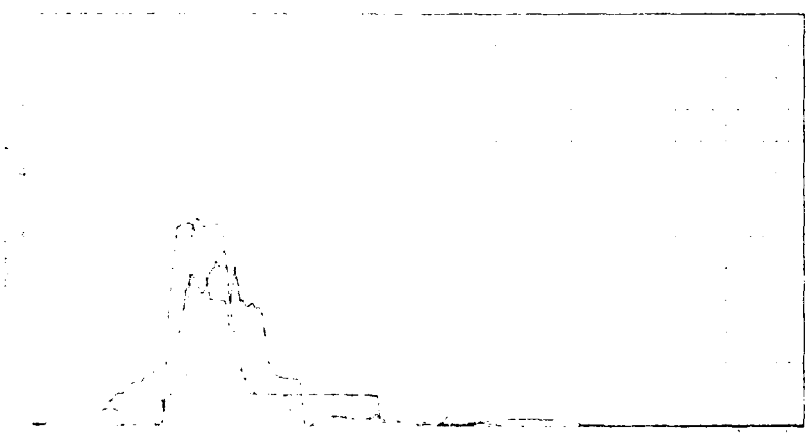
PLATE A-27



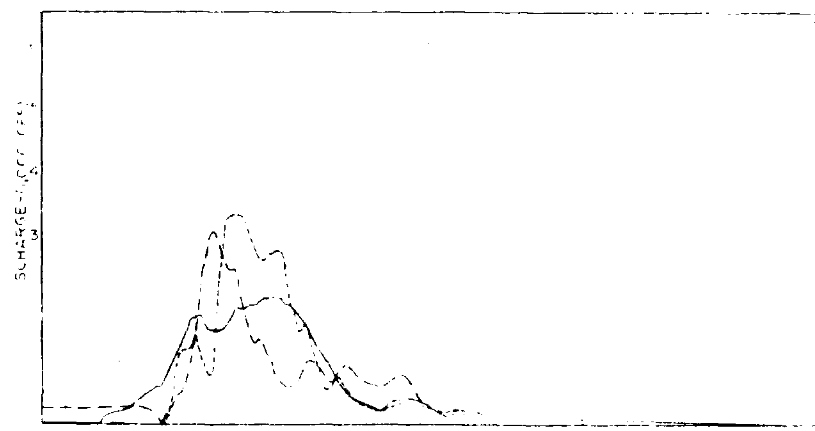
DISCHARGE HYDROGRAPH-SHERWOOD



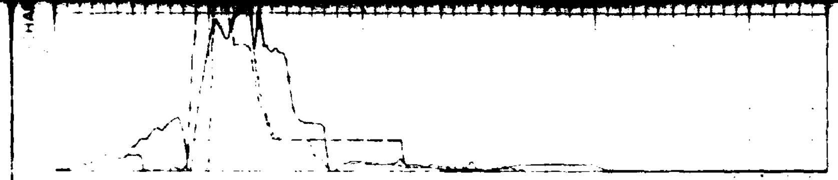
RESERVOIR STAGE HYDROGRAPHS



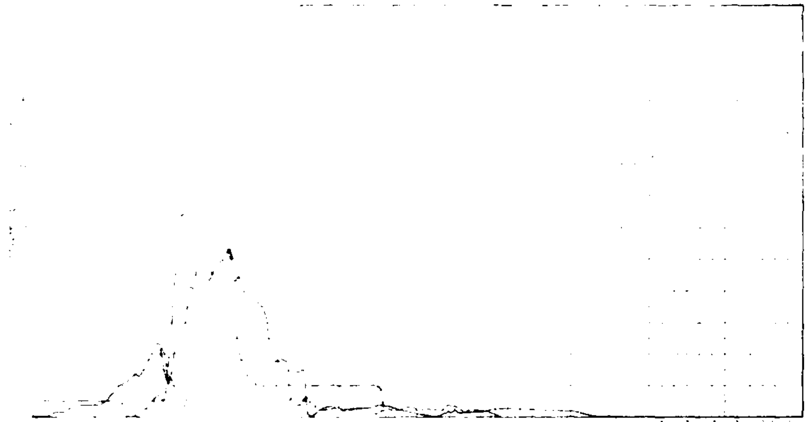
DISCHARGE HYDROGRAPH
FOXHOLM GAGE



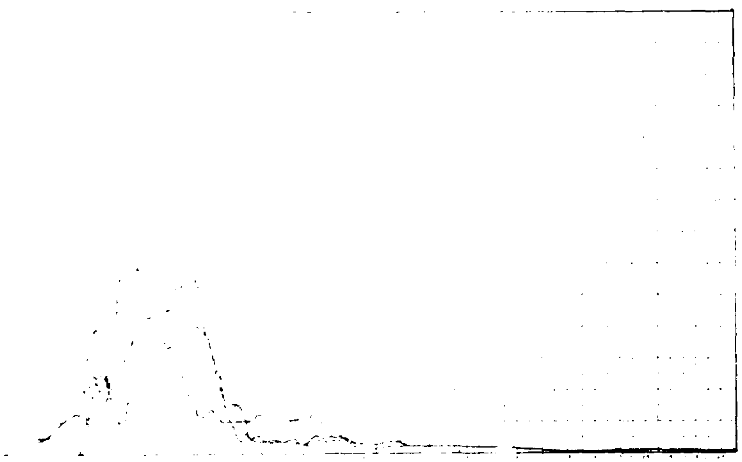
DISCHARGE HYDROGRAPH-BANTRY



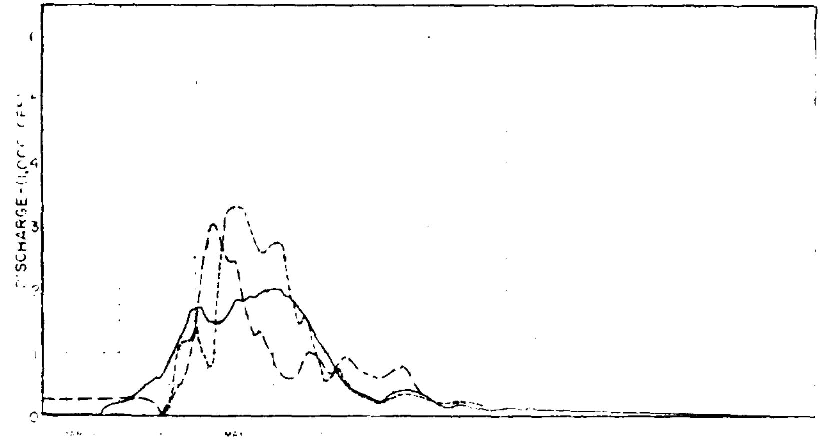
DISCHARGE HYDROGRAPH
FOXHOLM GAGE



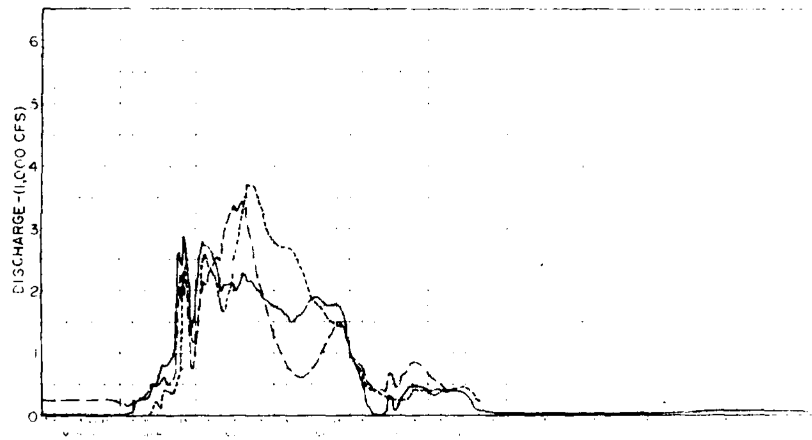
DISCHARGE HYDROGRAPH-MINOT



DISCHARGE HYDROGRAPH-VERENDRYE



DISCHARGE HYDROGRAPH-BANTRY



DISCHARGE HYDROGRAPH-WESTHOPE

——— EXISTING CONDITIONS
— — — MODIFIED CONDITIONS, PRIOR PROJECT
- - - - MODIFIED CONDITIONS, LAKE DARLING

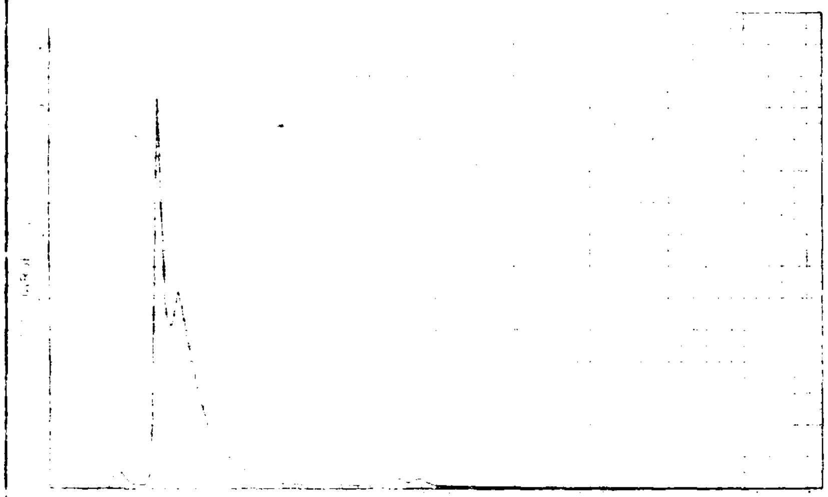
DESIGN MEMORANDUM NO 3
GENERAL
FLOOD CONTROL
SOURIS RIVER, NORTH DAKOTA

DISCHARGE AND LAKE ELEVATION HYDROGRAPHS
LAKE DARLING DAM OPERATION
YEAR - 1948

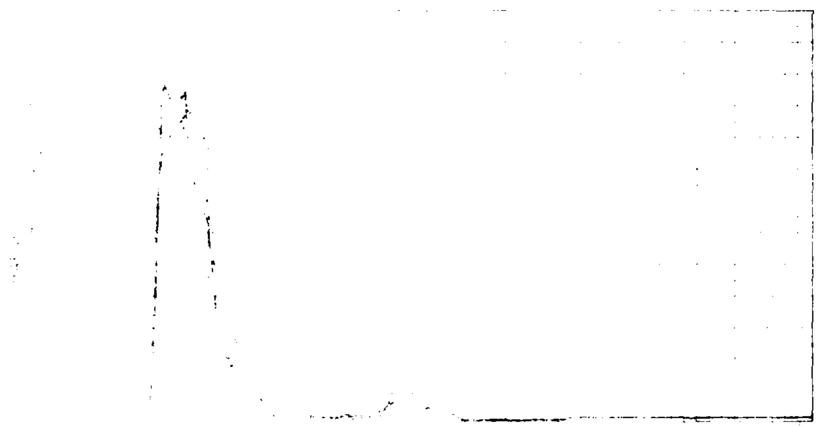
ST PAUL, MINN DISTRICT

FILE NO. RI--R-5/777 JUNE 1983

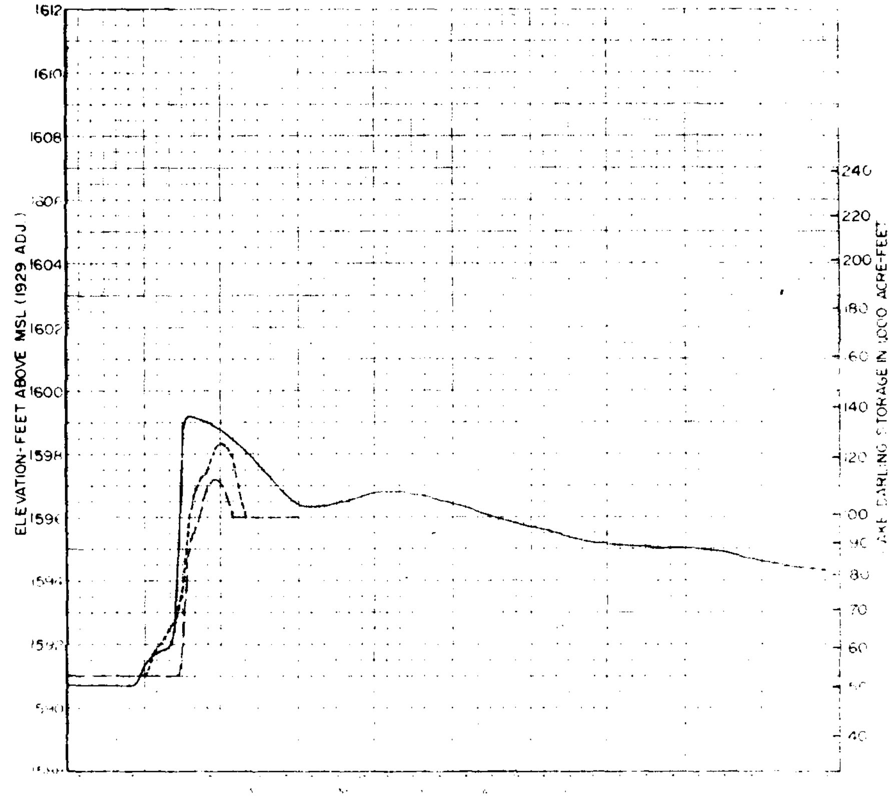
1 2



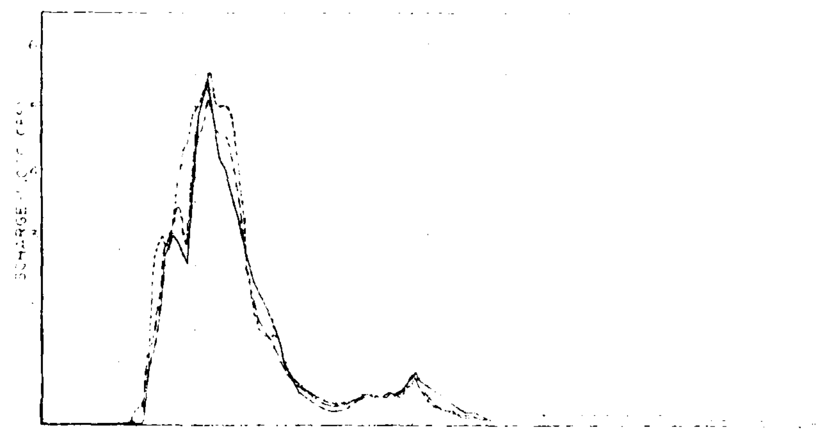
DISCHARGE HYDROGRAPH-SHERWOOD



DISCHARGE HYDROGRAPH
FOXHOLM GAGE

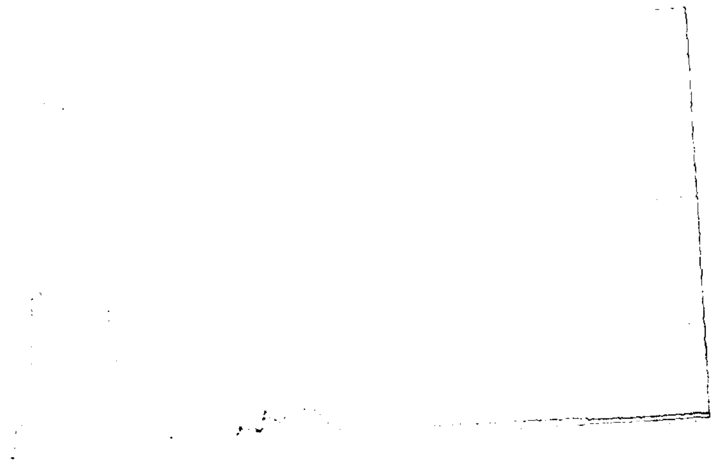


RESERVOIR STAGE HYDROGRAPHS

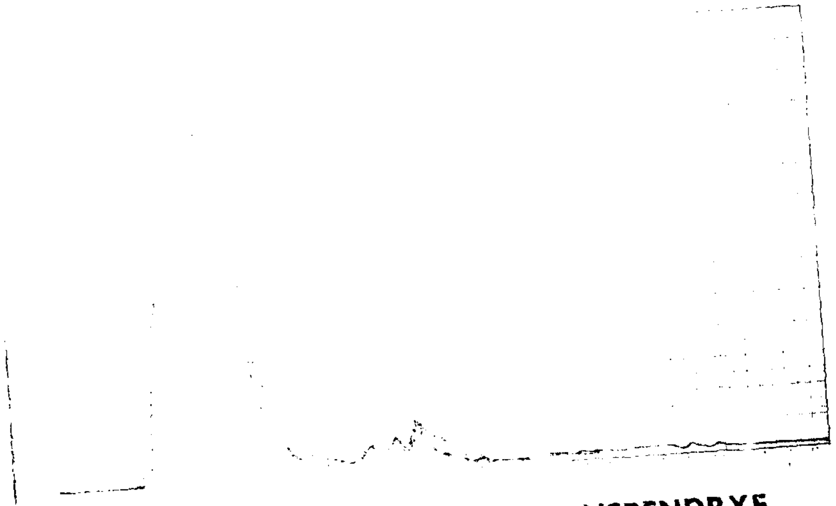


DISCHARGE HYDROGRAPH-BANTRY

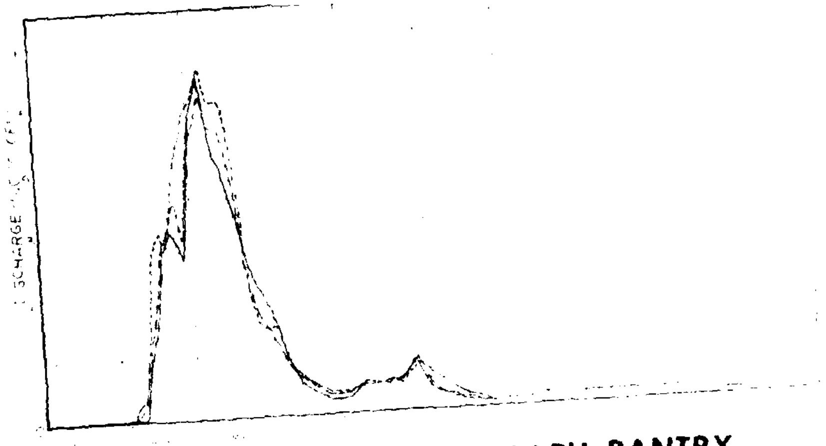
DISCHARGE HYDROGRAPH
FOXHOLM GAGE



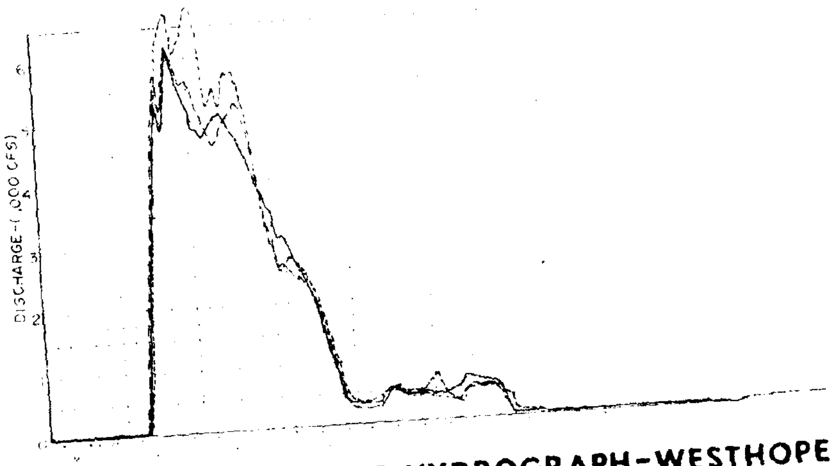
DISCHARGE HYDROGRAPH-MINOT



DISCHARGE HYDROGRAPH-VERENDRYE



DISCHARGE HYDROGRAPH-BANTRY



DISCHARGE HYDROGRAPH-WESTHOPE

EXISTING CONDITIONS
MODIFIED CONDITIONS, PRIOR PROJECT
MODIFIED CONDITIONS, LAKE DARLING

DESIGN MEMORANDUM NO 3
GENERAL
FLOOD CONTROL
SOURIS RIVER, NORTH DAKOTA
DISCHARGE AND LAKE ELEVATION HYDROGRAPHS
LAKE DARLING DAM OPERATION
YEAR - 1969

ST. PAUL, MINN. DISTRICT

FILE NO. R... 5277B

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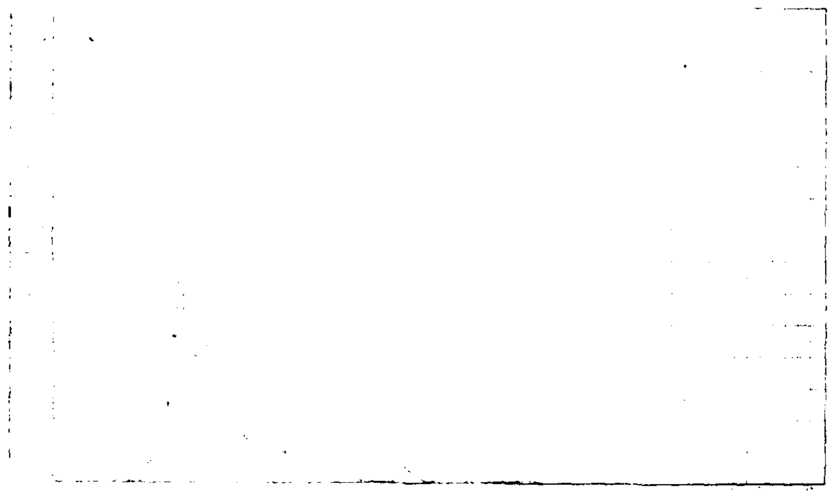
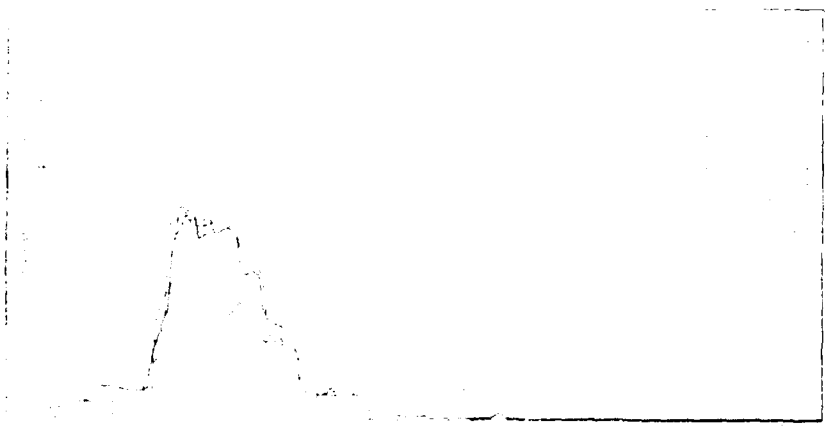
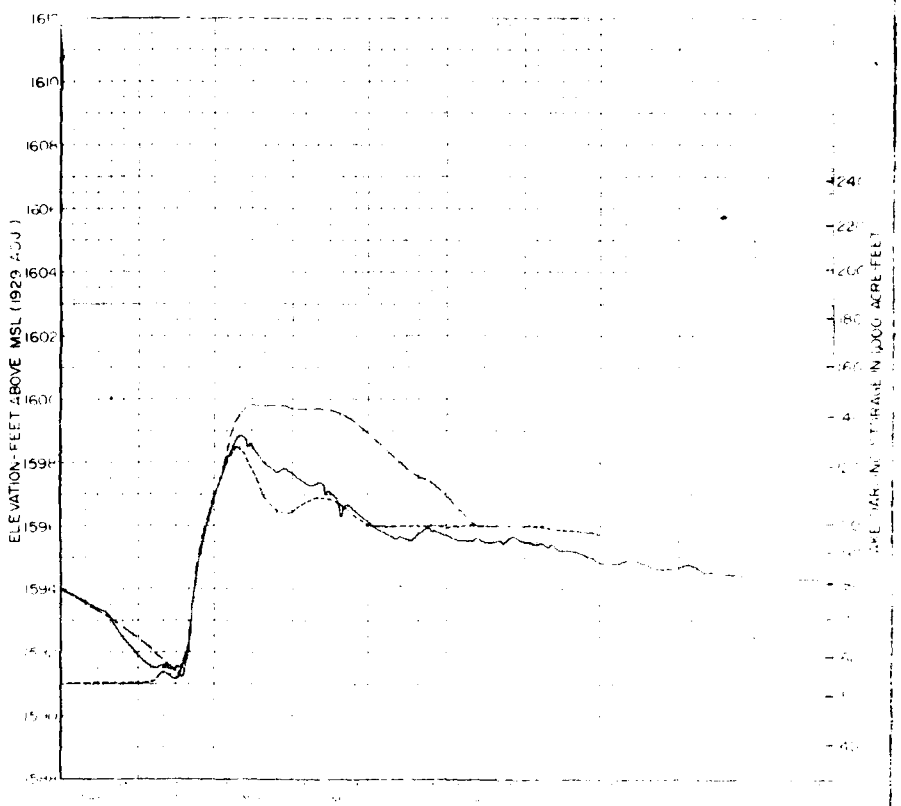


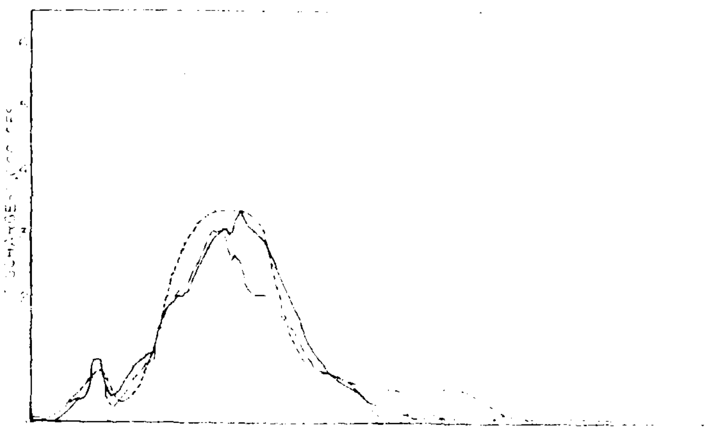
DISCHARGE HYDROGRAPH-SHERWOOD



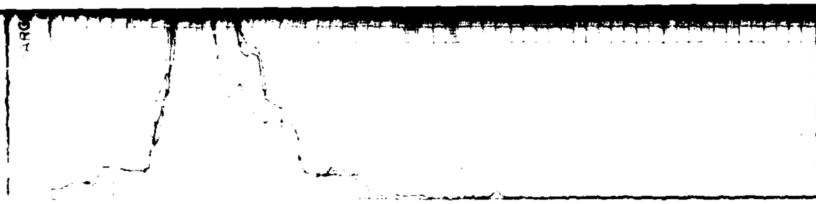
DISCHARGE HYDROGRAPH
FOXHOLM GAGE



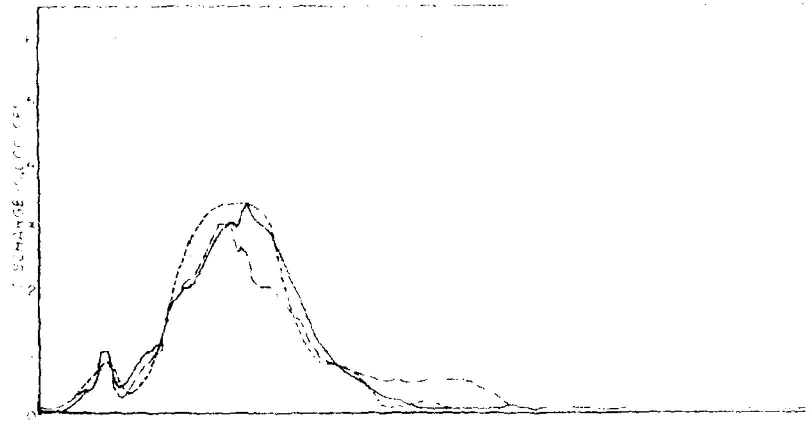
RESERVOIR STAGE HYDROGRAPHS



DISCHARGE HYDROGRAPH-BANTRY

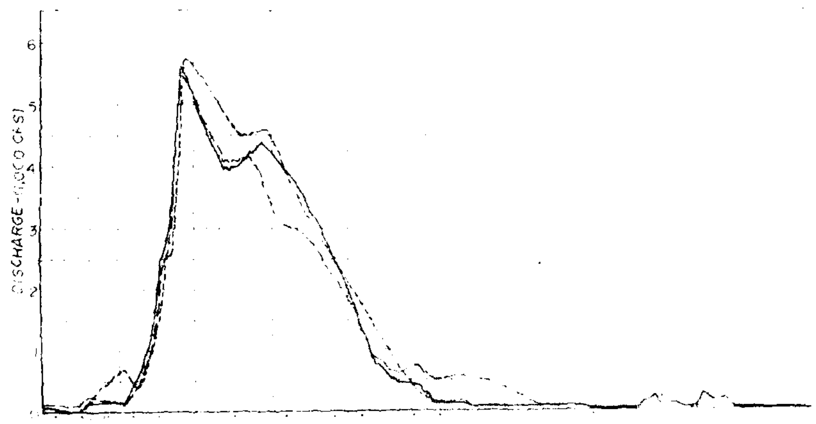


DISCHARGE HYDROGRAPH
FOXHOLM GAGE



DISCHARGE HYDROGRAPH-BANTRY

DISCHARGE HYDROGRAPH-MINOT



DISCHARGE HYDROGRAPH-WESTHOPE

DISCHARGE HYDROGRAPH-VERENDRYE

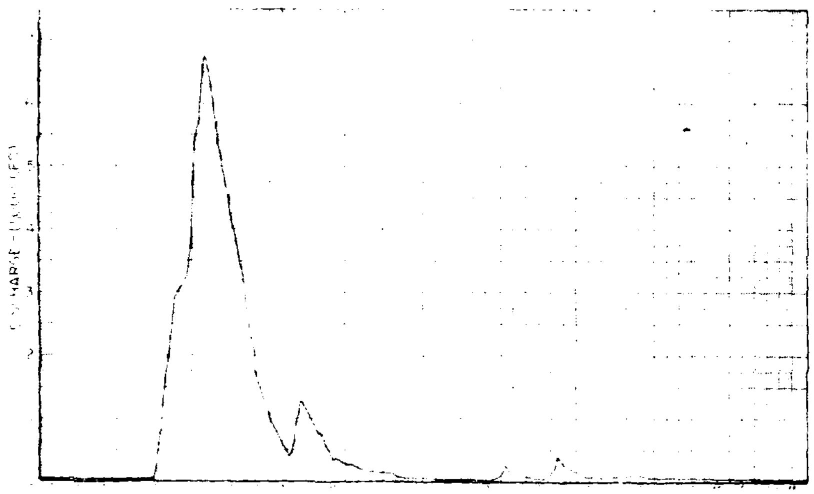
EXISTING CONDITIONS
MODIFIED CONDITIONS, PRIOR PROJECT
MODIFIED CONDITIONS, LAKE DARLING

DESIGN MEMORANDUM NO. 3
GENERAL
FLOOD CONTROL
SOURIS RIVER, NORTH DAKOTA

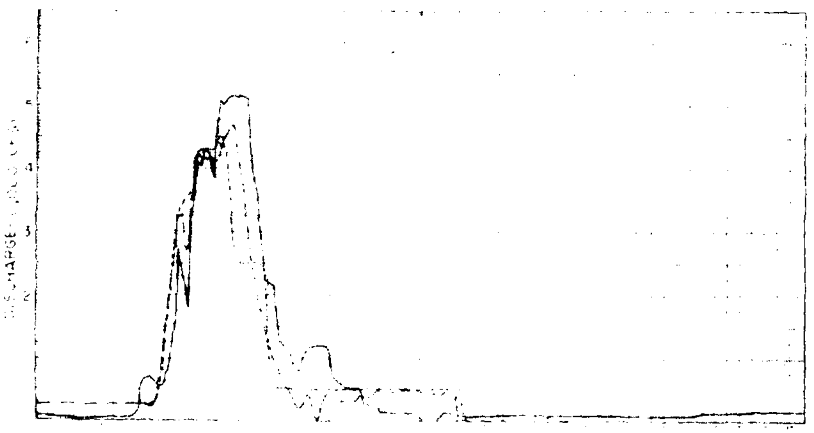
DISCHARGE AND LAKE ELEVATION HYDROGRAPHS
LAKE DARLING DAM OPERATION
YEAR - 1974

ST. PAUL, MINN. DISTRICT

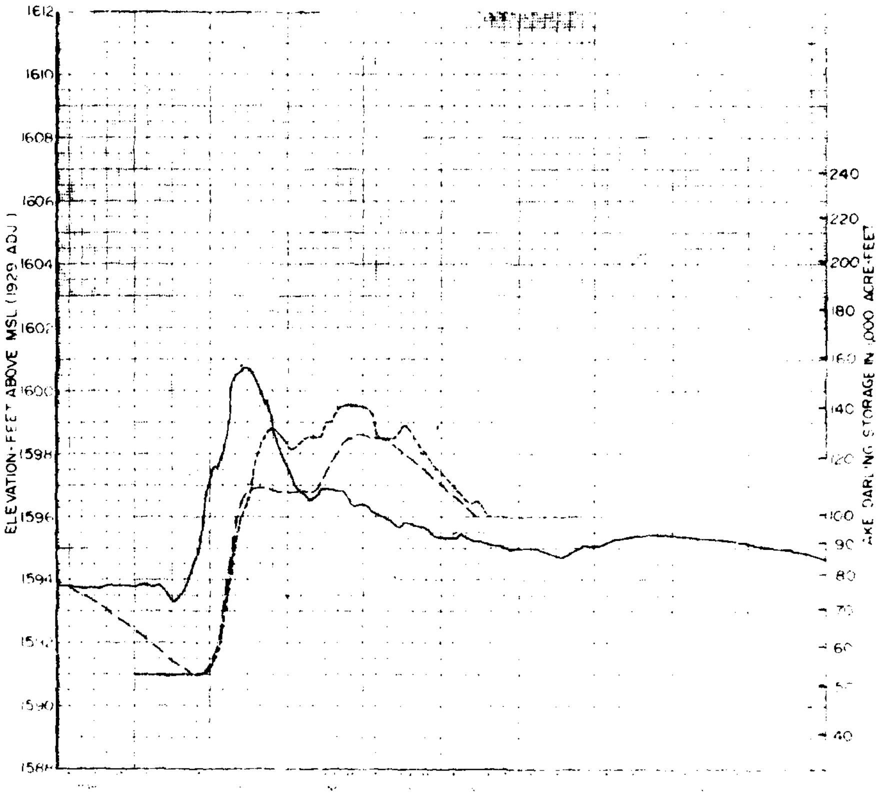
FILE NO. RI R [illegible]



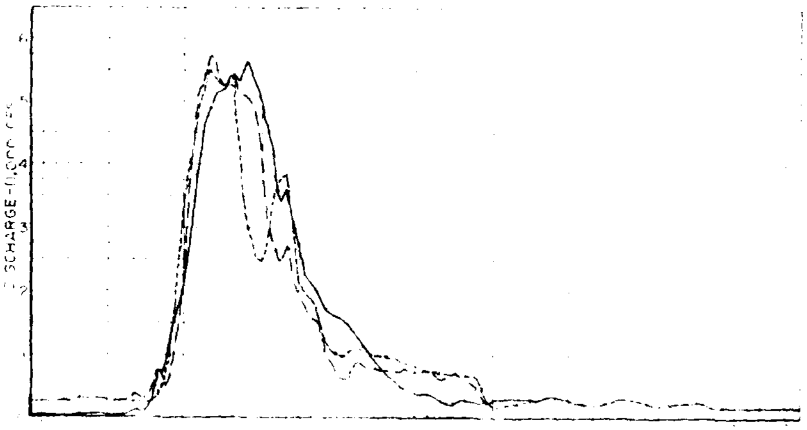
DISCHARGE HYDROGRAPH-SHERWOOD



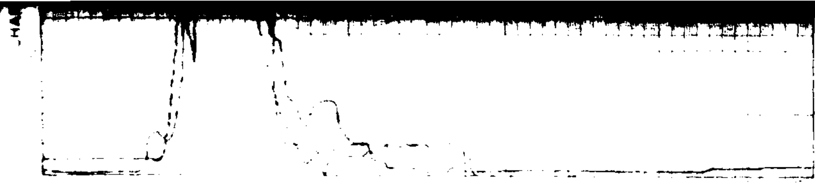
DISCHARGE HYDROGRAPH
FOXHOLM GAGE



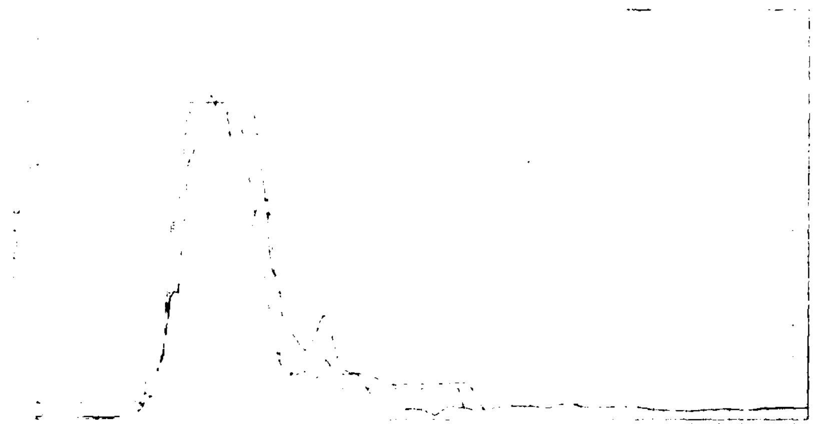
RESERVOIR STAGE HYDROGRAPHS



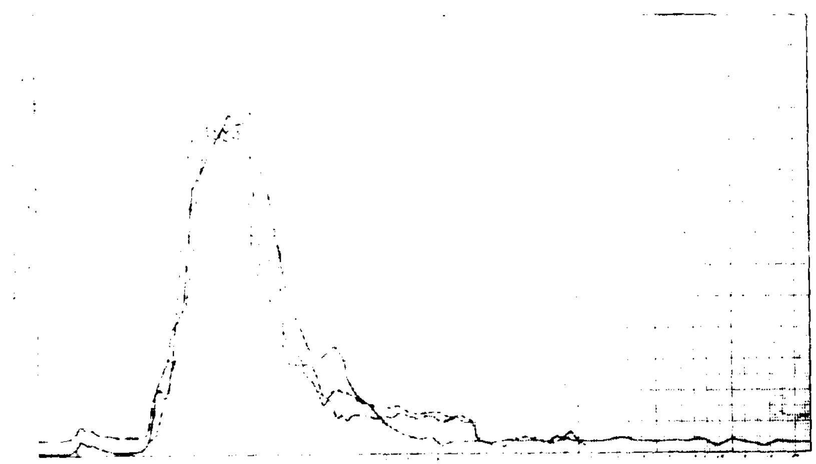
DISCHARGE HYDROGRAPH-BANTRY



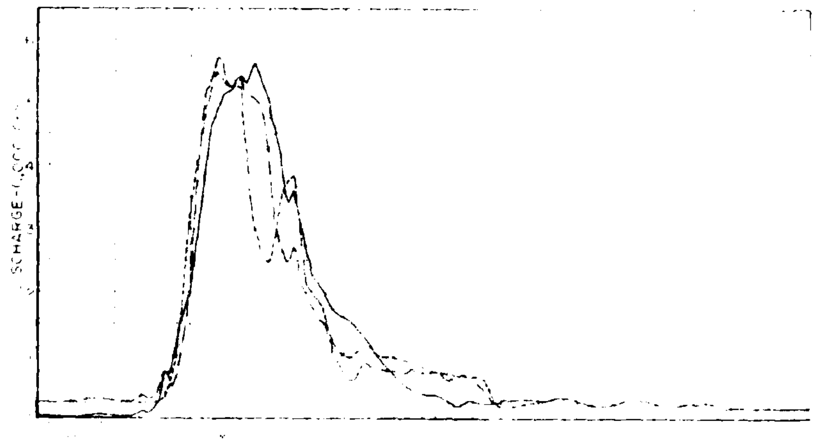
DISCHARGE HYDROGRAPH
FOXHOLM GAGE



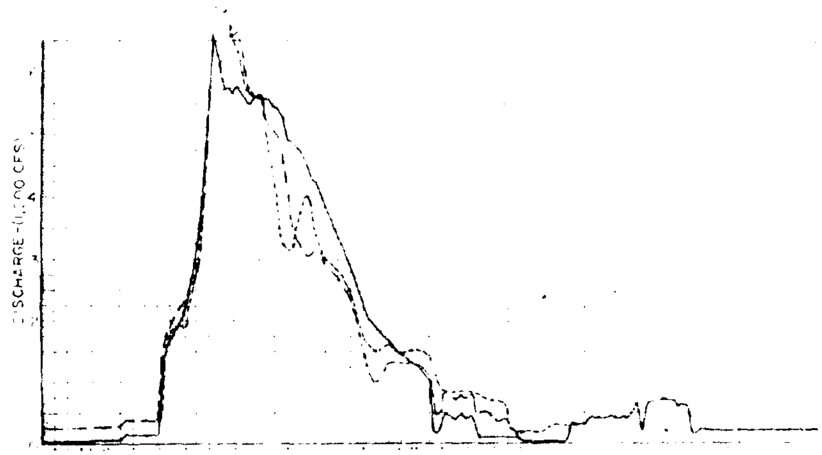
DISCHARGE HYDROGRAPH-MINOT



DISCHARGE HYDROGRAPH-''ERENDRYE



DISCHARGE HYDROGRAPH-BANTRY



DISCHARGE HYDROGRAPH-WESTHOPE

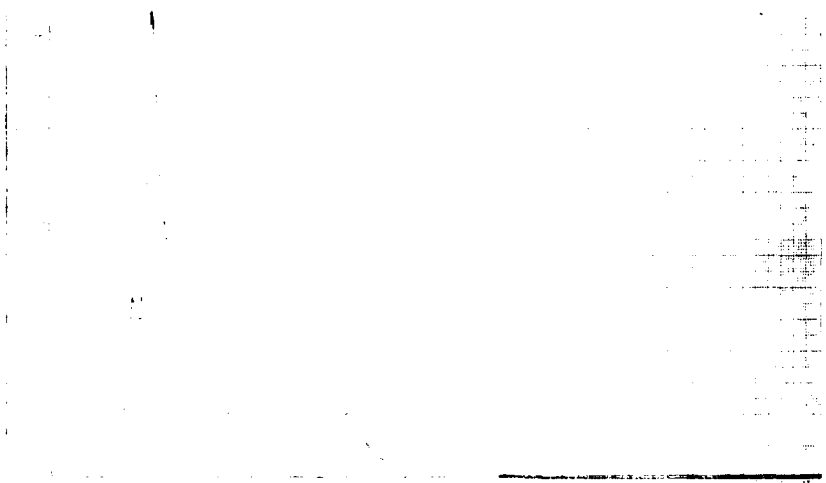
EXISTING CONDITIONS
MODIFIED CONDITIONS, PRIOR PROJECT
MODIFIED CONDITIONS, LAKE DARLING

DESIGN MEMORANDUM NO. 3
GENERAL
FLOOD CONTROL
SOURIS RIVER, NORTH DAKOTA

DISCHARGE AND LAKE ELEVATION HYDROGRAPHS
LAKE DARLING DAM OPERATION
YEAR - 1975

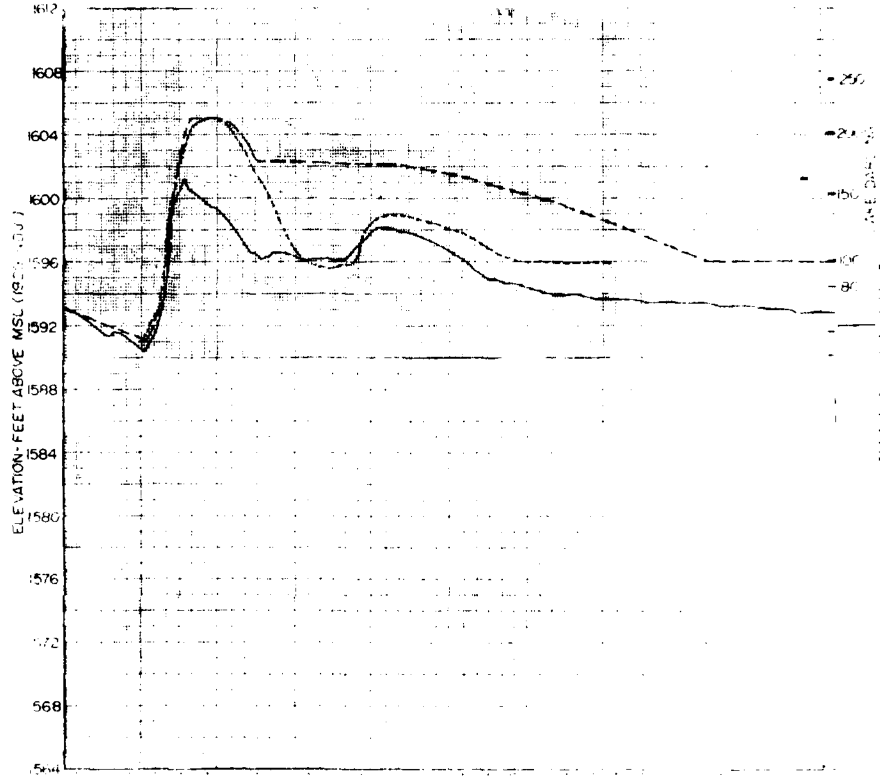
ST. PAUL, MINN. DISTRICT

1 2



DISCHARGE HYDROGRAPH-SHERWOOD

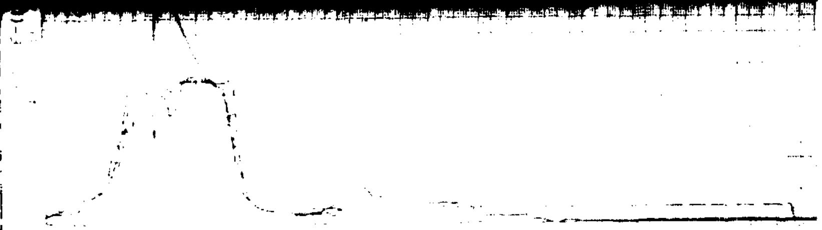
DISCHARGE HYDROGRAPH
FOXHOLM GAGE



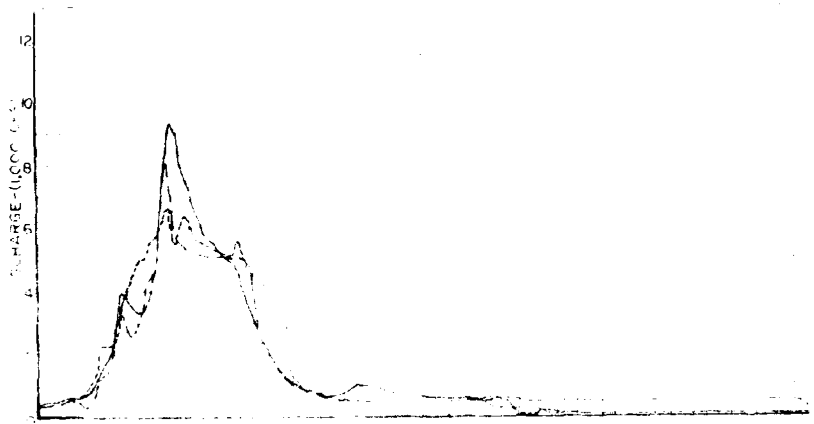
RESERVOIR STAGE HYDROGRAPHS

DISCHARGE HYDROGRAPH-BANTRY

RESERVOIR STAGE HYDROGRAPHS



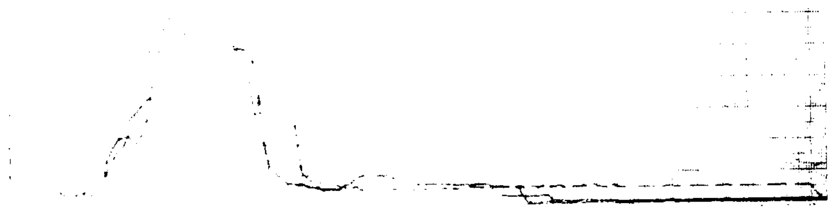
DISCHARGE HYDROGRAPH
FOXHOLM GAGE



DISCHARGE HYDROGRAPH-BANTRY

DISCHARGE HYDROGRAPH-MINOT

DISCHARGE HYDROGRAPH-WESTHOPE



DISCHARGE HYDROGRAPH-VERENDRYE

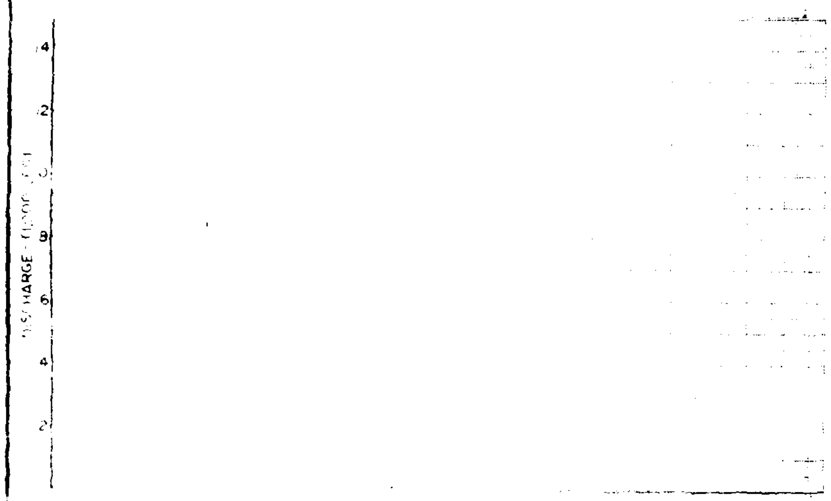
EXISTING CONDITIONS
MODIFIED CONDITIONS, PRIOR PROJECT
MODIFIED CONDITIONS, LAKE DARLING

DESIGN MEMORANDUM NO. 4
GENERAL
FLOOD CONTROL
SOURIS RIVER, NORTH DAKOTA

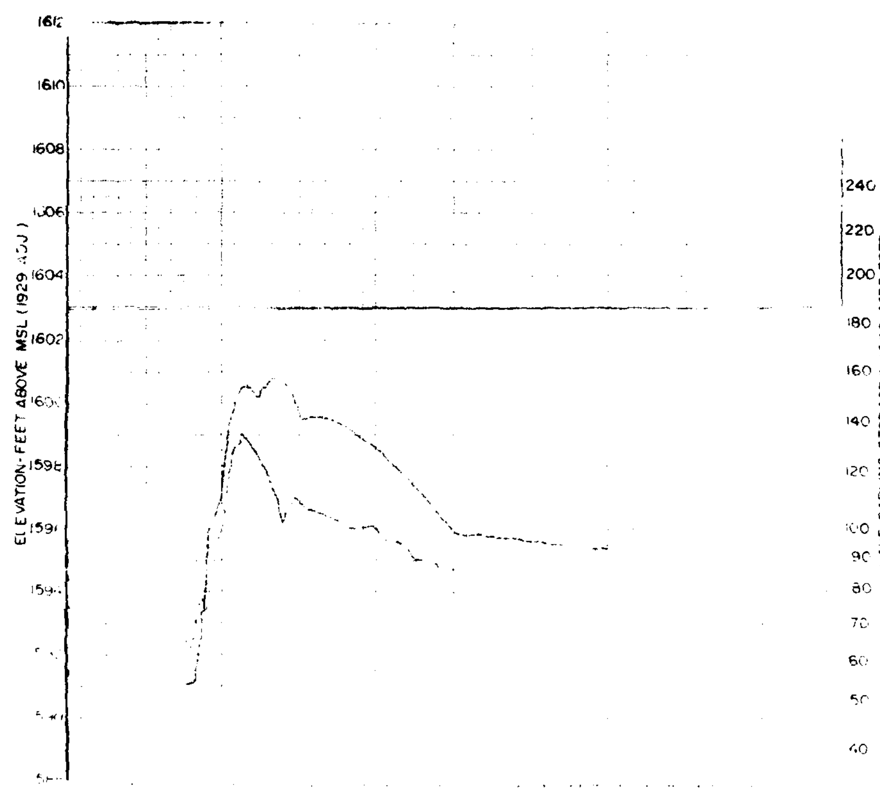
DISCHARGE AND LAKE ELEVATION HYDROGRAPHS
LAKE DARLING DAM OPERATION
YEAR - 1976

ST. PAUL, MINN. DISTRICT
FILE NO. [illegible]

1 2

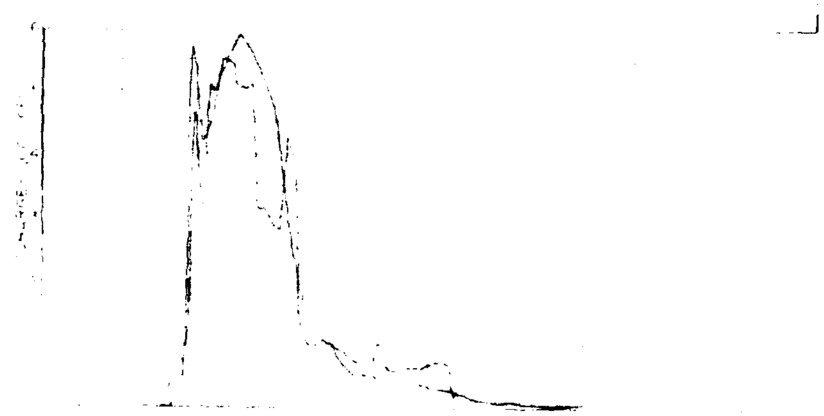


DISCHARGE HYDROGRAPH-SHERWOOD

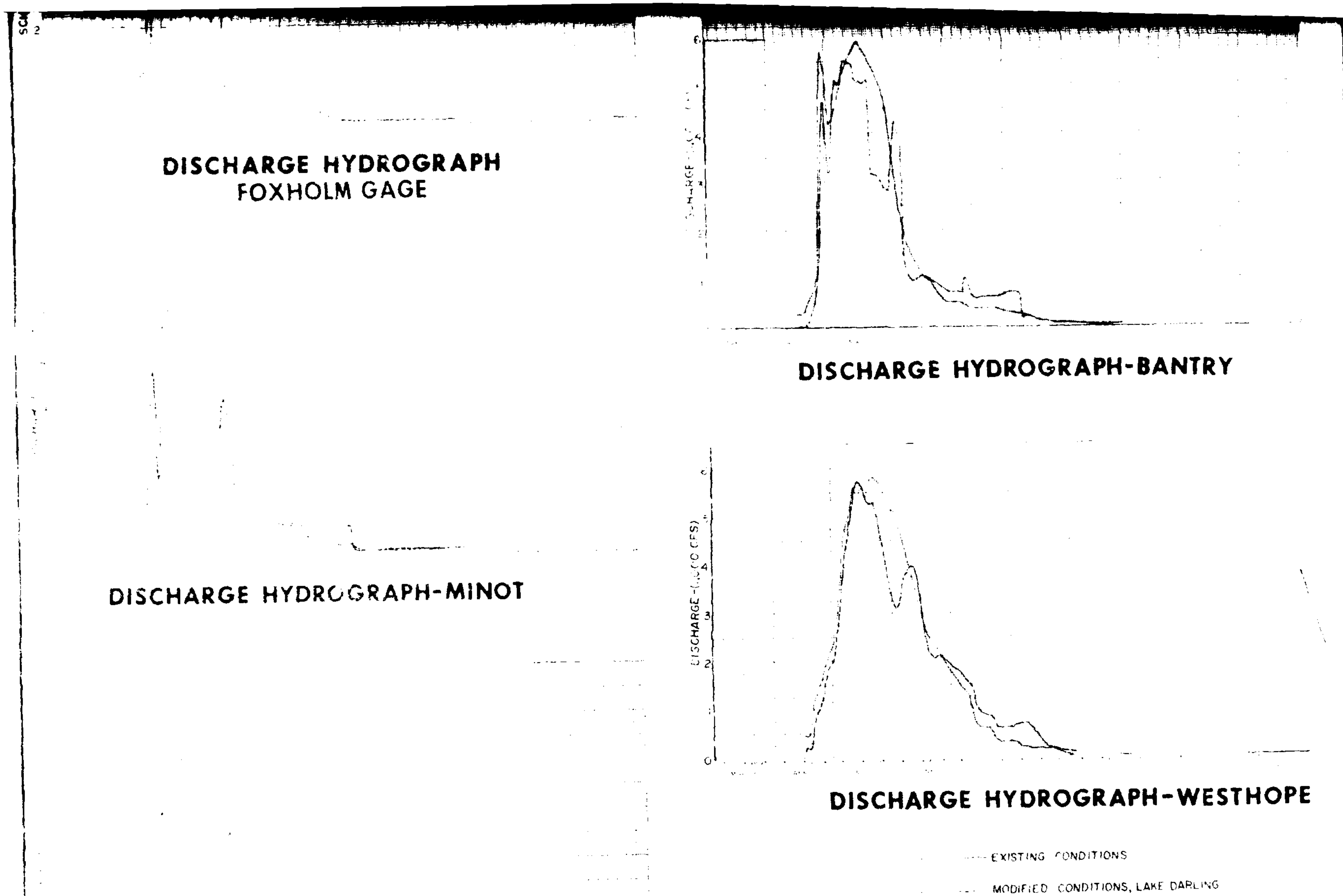


RESERVOIR STAGE HYDROGRAPHS

DISCHARGE HYDROGRAPH
FOXHOLM GAGE



DISCHARGE HYDROGRAPH-BANTRY



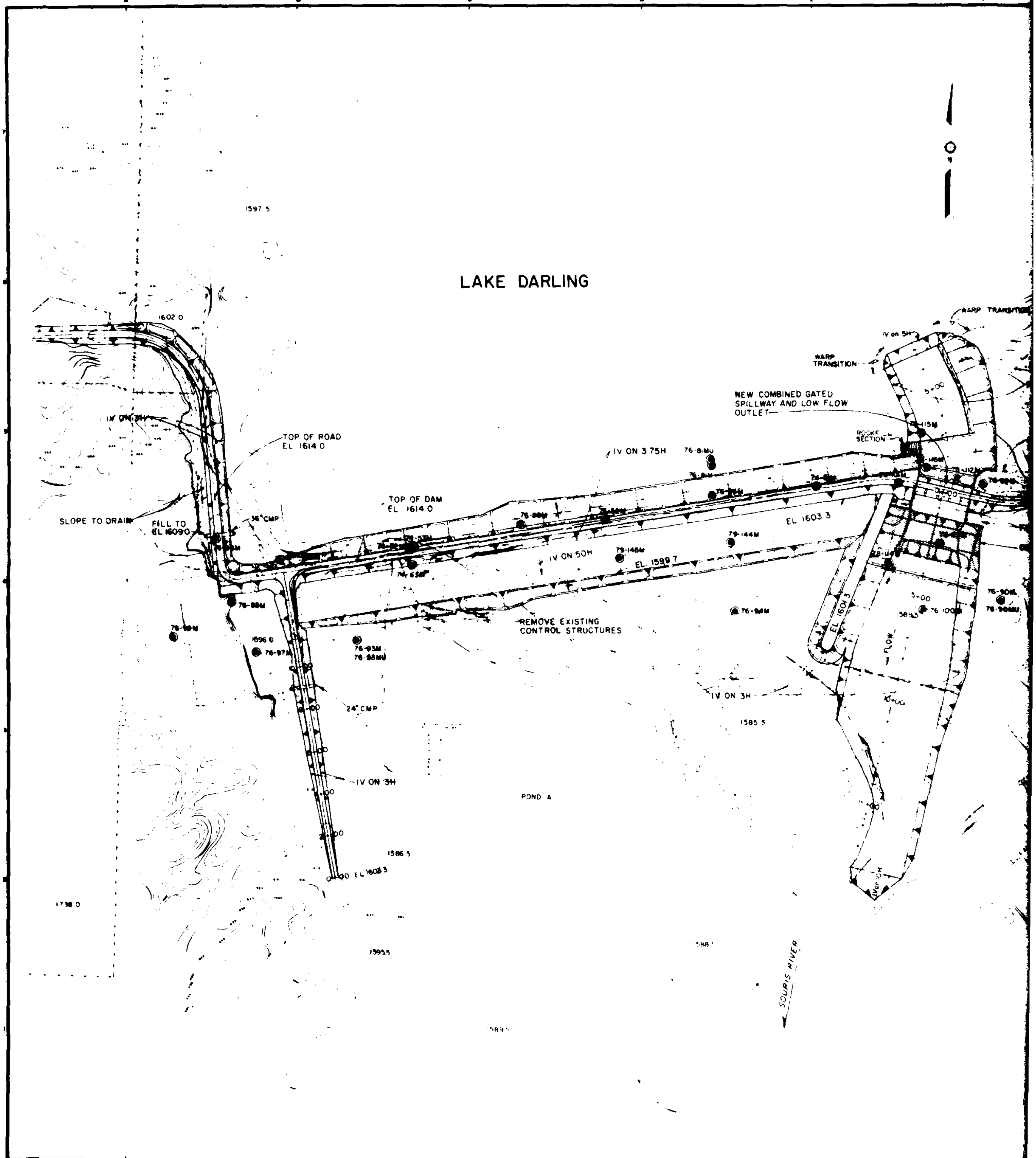
DESIGN MEMORANDUM NO. 3
GENERAL
FLOOD CONTROL
SOURIS RIVER, NORTH DAKOTA

DISCHARGE AND LAKE ELEVATION HYDROGRAPHS
LAKE DARLING DAM OPERATION
YEAR - 1979

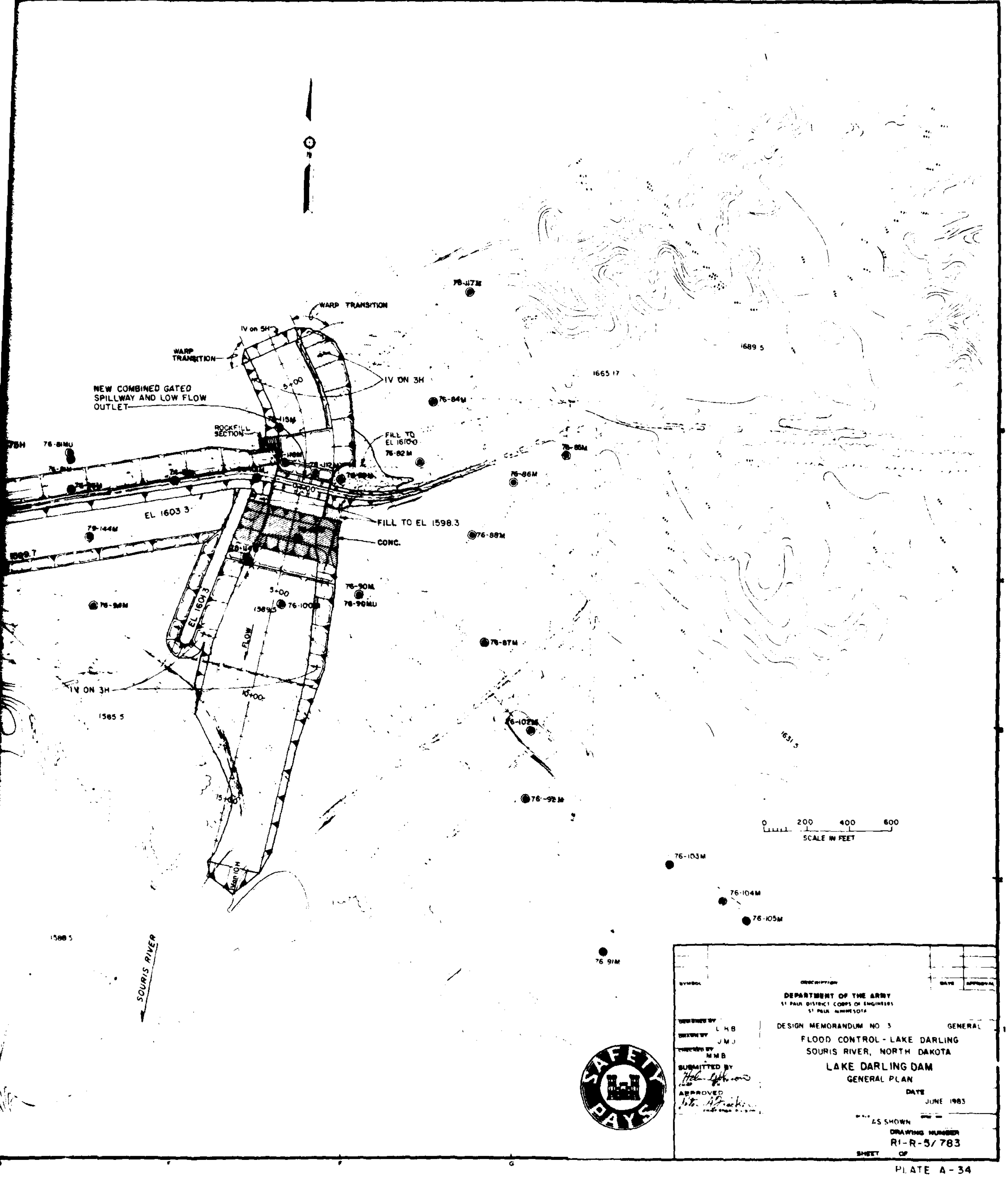
ST. PAUL, MINN. DISTRICT
FILE NO. RI-R-5/782

2

CORPS OF ENGINEERS



U. S. ARMY



DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY L.H.B.
DRAWN BY J.M.J.
CHECKED BY M.M.B.
SUBMITTED BY
APPROVED

DESIGN MEMORANDUM NO. 3 GENERAL

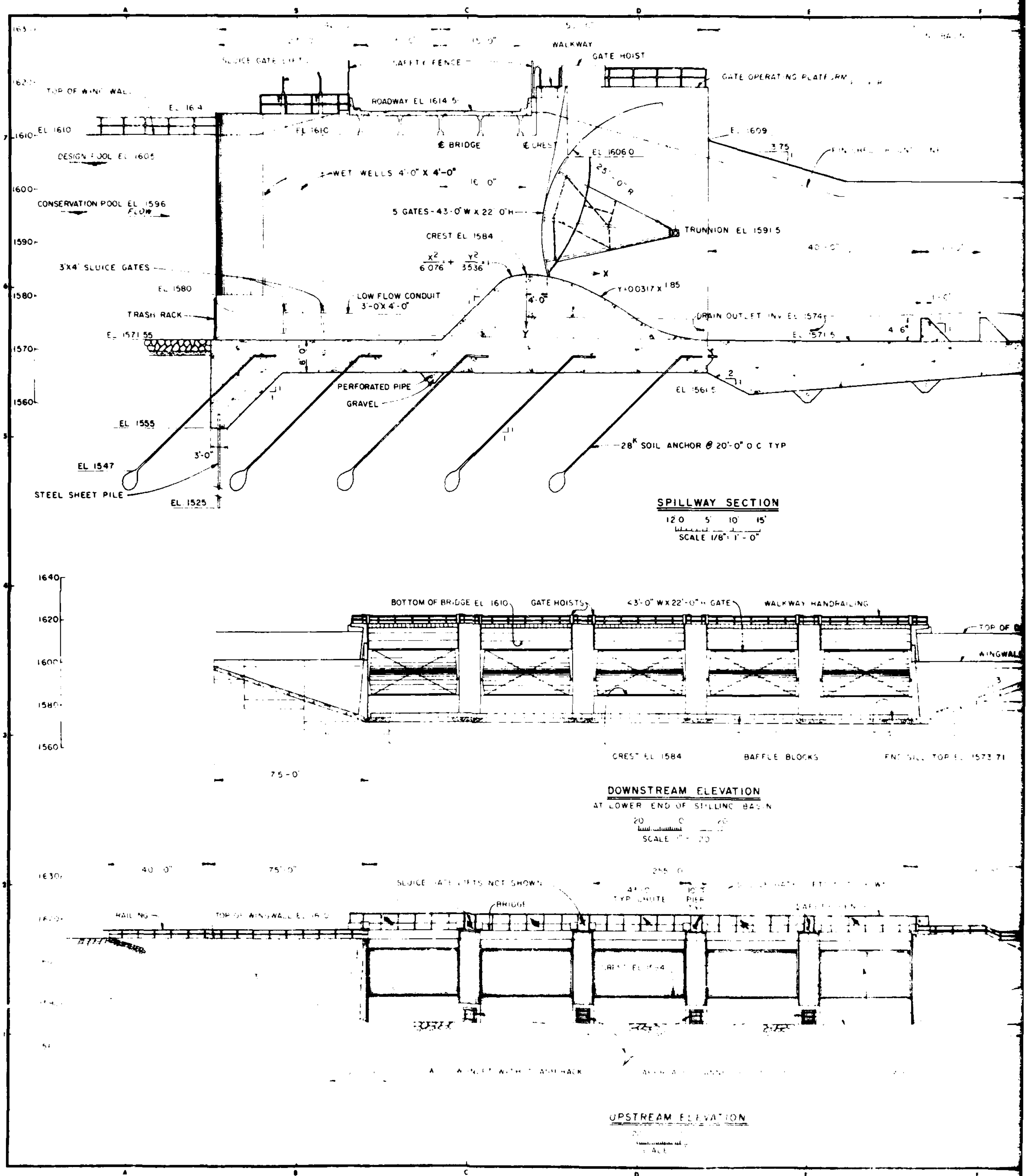
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

LAKE DARLING DAM
GENERAL PLAN

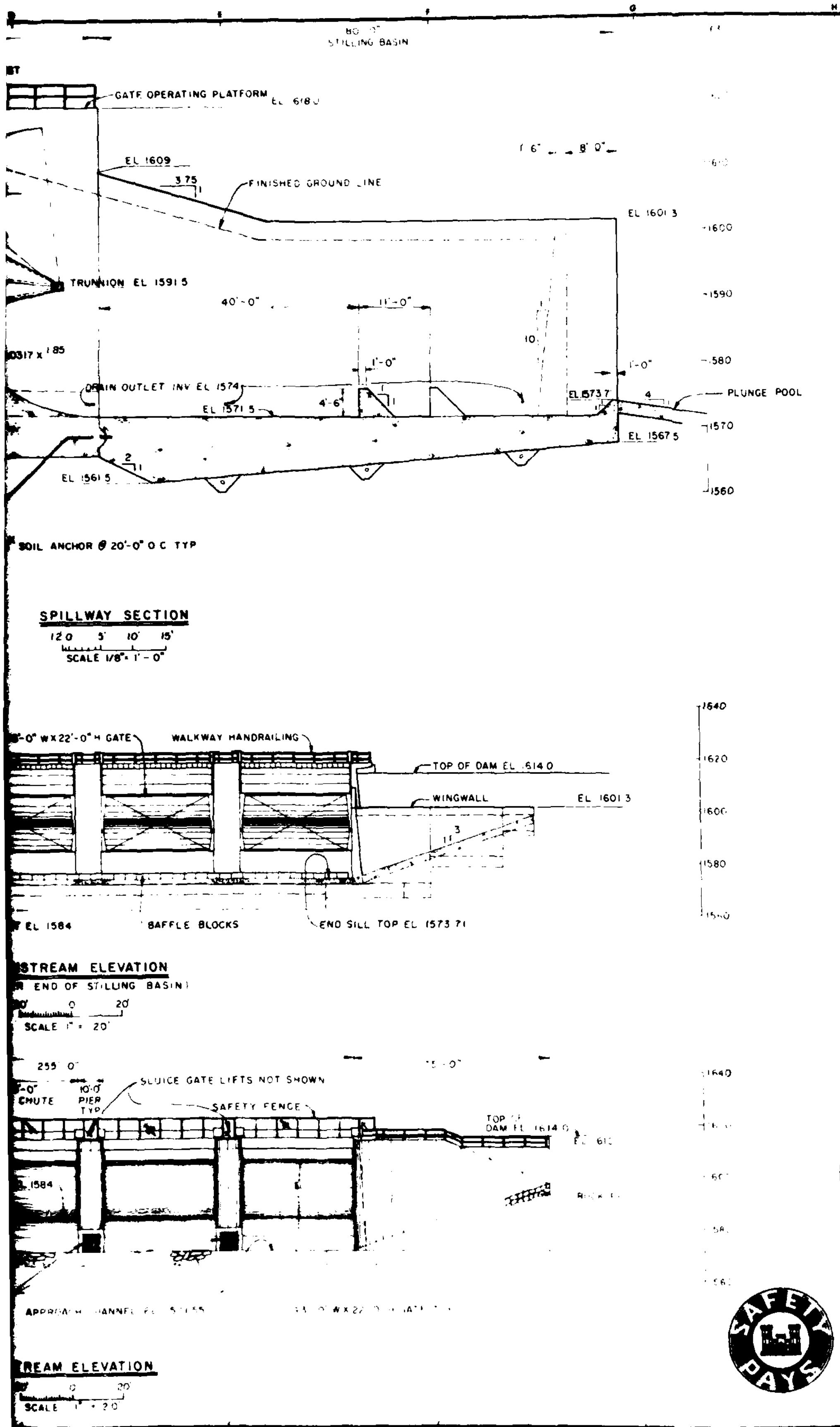
DATE JUNE 1983
SCALE AS SHOWN
DRAWING NUMBER R1-R-5/783
SHEET OF

SAFETY PAYS

2



WALKWAY
GATE HOIST
SAFETY FENCE
GATE OPERATING PLATFORM
TOP OF WING WALL
ROADWAY EL 1614.5
EL 1610
℄ BRIDGE
DESIGN POOL EL 1605
EL 1606.0
WET WELLS 4'-0" X 4'-0"
CONSERVATION POOL EL 1596
FLOW
5 GATES-43-0"W X 22'-0"H
TRUNNION EL 1591.5
CREST EL 1584
3'X4' SLUICE GATES
EL 1580
LOW FLOW CONDUIT 3'-0"X 4'-0"
TRASH RACK
DRAIN OUTLET INV EL 1574
EL 1571.55
EL 1571.5
PERFORATED PIPE
GRAVEL
EL 1561.5
EL 1555
EL 1547
28K SOIL ANCHOR @ 20'-0" O.C. TYP
STEEL SHEET PILE
EL 1525
SPILLWAY SECTION
SCALE 1/8" = 1'-0"
BOTTOM OF BRIDGE EL 1610
GATE HOISTS
43'-0" W X 22'-0" H GATE
WALKWAY HANDRAILING
CREST EL 1584
BAFFLE BLOCKS
DOWNSTREAM ELEVATION
AT LOWER END OF STILLING BASIN
SLUICE GATE LIFTS NOT SHOWN
BRIDGE
RAILING
TYP CHUTE
PIER
UPSTREAM ELEVATION



DEPARTMENT OF THE ARMY
ST PAUL DISTRICT CORPS OF ENGINEERS
ST PAUL MINNESOTA

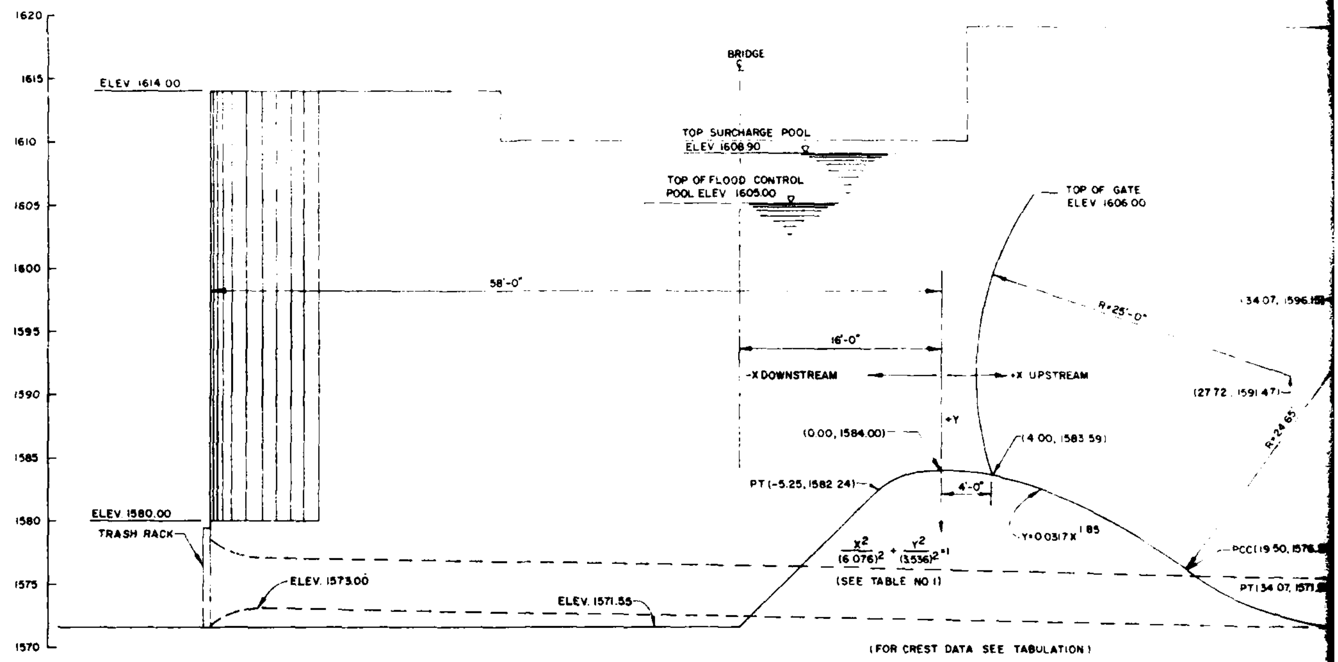
DESIGN MEMORANDUM NO 3 GENERAL
FLOOD CONTROL LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
LAKE DARLING DAM
SPILLWAY

SUBMITTED BY

DRAWING NUMBER
RI-R-5/784

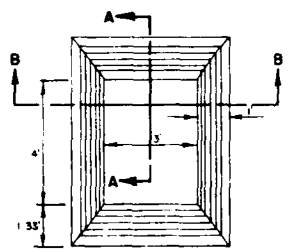
PLATE A-35

1 2



SPILLWAY CREST DETAIL

SCALE 1" = 5'-0"

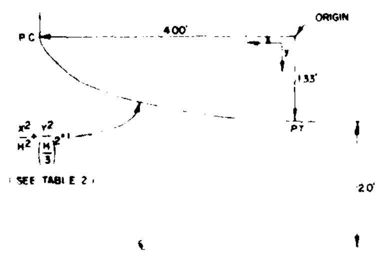


FLUSH SLUICE INTAKE

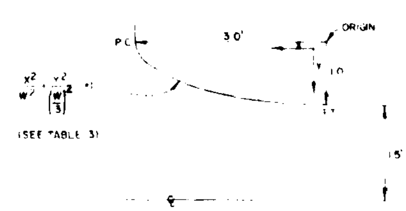
SCALE 1" = 2'-0"

TABLE 2

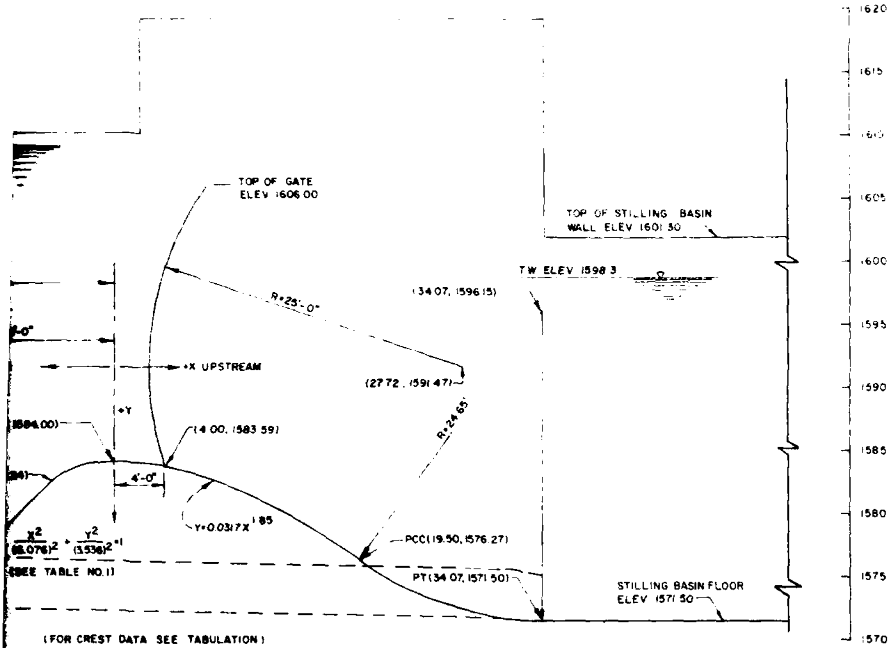
$x^2/(4)^2 + y^2/(4/3)^2 = 1$	
X	Y
0.00	1.33
0.25	1.33
0.50	1.32
0.75	1.31
1.00	1.29
1.25	1.27
1.50	1.24
1.75	1.20
2.00	[illegible]
2.25	[illegible]
2.50	1.04
2.75	[illegible]
[illegible]	0.88
3.25	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
4.[illegible]	[illegible]



SECTION A-A



SECTION B-B



SPILLWAY CREST DETAIL

SCALE 1"=5'-0"

TABLE 1
CREST COORDINATES

UPSTREAM QUADRANT			DOWNSTREAM QUADRANT		
$X^2/(6.076)^2+Y^2/(3.536)^2=1$			$X^{1.85}=2.05\,Hd^{0.85}\,Y$		
X	Y	ELEV	X	Y	ELEV
-0.00	0.000	1584.00	0.0	0.000	1584.00
-0.25	0.003	1584.00	0.5	0.009	1583.99
-0.50	0.012	1583.99	1.0	0.032	1583.97
-0.75	0.027	1583.97	1.5	0.067	1583.93
-1.00	0.048	1583.95	2.0	0.114	1583.89
1.25	0.076	1583.92	2.5	0.173	1583.83
-1.50	0.109	1583.89	3.0	0.242	1583.76
-1.75	0.150	1583.85	3.5	0.322	1583.68
-2.00	0.197	1583.80	4.0	0.412	1583.59
-2.25	0.251	1583.75	4.5	0.513	1583.49
-2.50	0.313	1583.69	5.0	0.623	1583.38
-2.75	0.383	1583.62	5.5	0.743	1583.26
-3.00	0.461	1583.54	6.0	0.873	1583.13
-3.25	0.548	1583.45	6.5	1.012	1582.99
-3.50	0.645	1583.35	7.0	1.161	1582.84
-3.75	0.754	1583.25	7.5	1.319	1582.68
-4.00	0.874	1583.13	8.0	1.487	1582.51
-4.25	1.009	1582.99	8.5	1.663	1582.34
-4.50	1.160	1582.84	9.0	1.848	1582.[illegible]
-4.75	1.331	1582.67	9.5	2.043	1581.96
-5.00	1.527	1582.47	10.0	2.246	1581.75
-5.25	1.756	1582.24	10.5	2.458	1581.54
			11.0	2.679	1581.32
			11.5	2.909	1581.09
			12.0	3.147	1580.85
			12.5	3.394	1580.61
			13.0	3.650	1580.35
			13.5	3.914	1580.09
			14.0	4.186	1579.81
			14.5	4.467	1579.53
			15.0	4.756	1579.24
			15.5	5.053	1578.95
			16.0	5.359	1578.64
			16.5	5.673	1578.33
			17.0	5.995	1578.00
			17.5	6.325	1577.67
			18.0	6.664	1577.34
			18.5	7.010	1576.99
			19.0	7.365	1576.63
			19.5	7.727	1576.27

TABLE 2

$X^2/(4)^2+Y^2/(4/3)^2=1$	
X	Y
0.00	1.33
0.25	1.33
0.50	1.32
0.75	1.31
1.00	1.29
1.25	1.27
1.50	1.24
1.75	1.20
2.00	1.15
2.25	1.10
2.50	1.04
2.75	0.97
3.00	0.88
3.25	0.77
3.50	0.64
3.75	0.46
4.00	0.00

TABLE 3

$X^2/(3)^2+Y^2/(3/3)^2=1$	
X	Y
0.00	1.00
0.25	1.00
0.56	0.99
0.75	0.97
1.00	0.94
1.25	0.91
1.50	0.87
1.75	0.81
2.00	0.74
2.25	0.66
2.50	0.55
2.75	0.40
3.00	0.00

SYMBOL | DESCRIPTION | DATE | APPROVAL

DEPARTMENT OF THE ARMY
ST PAUL DISTRICT CORPS OF ENGINEERS
ST PAUL, MINNESOTA

DESIGNED BY
DRAWN BY
CHECKED BY
SUBMITTED BY
APPROVED

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

LAKE DARLING DAM

SPILLWAY DETAILS

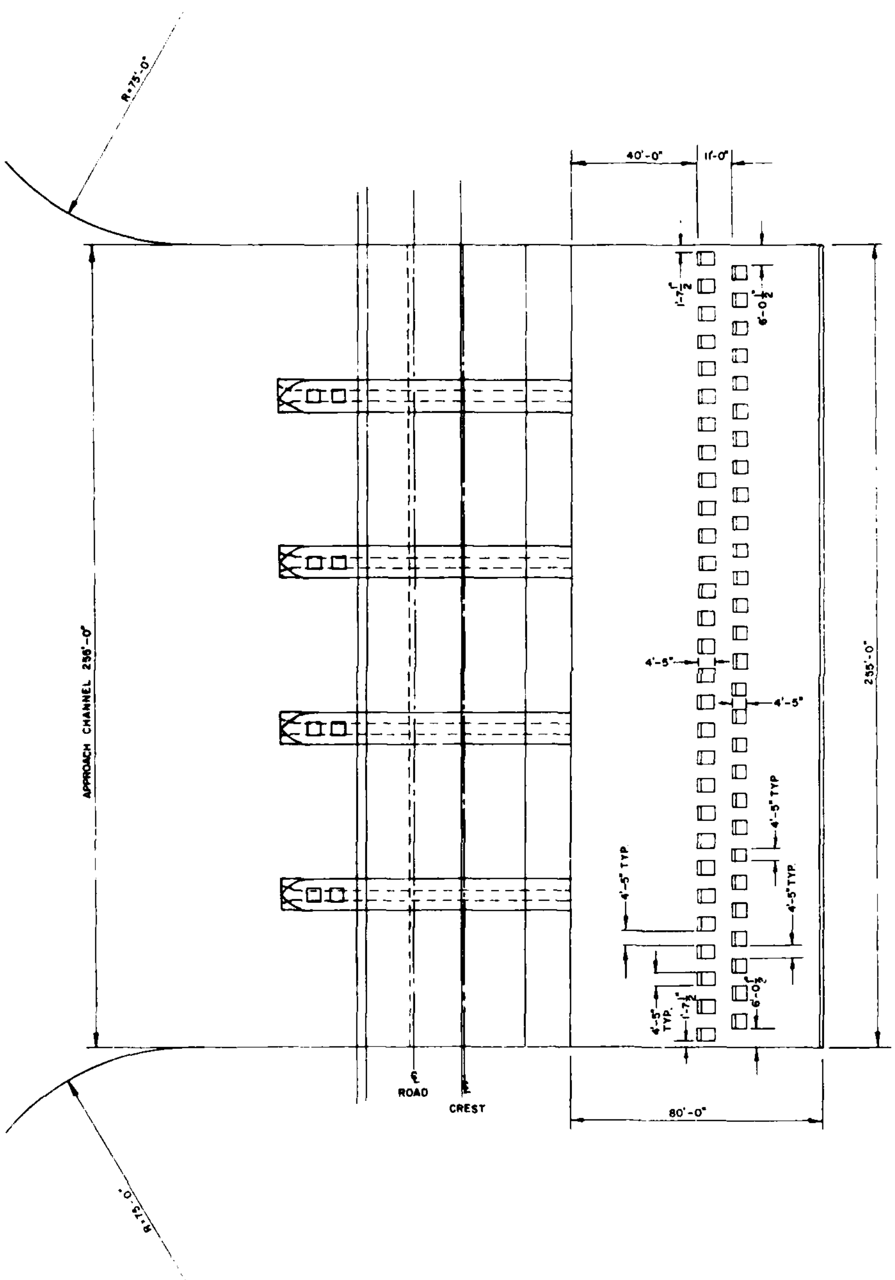
DATE JUNE 1983

AS SHOWN

DRAWING NUMBER
R-RI-5/785

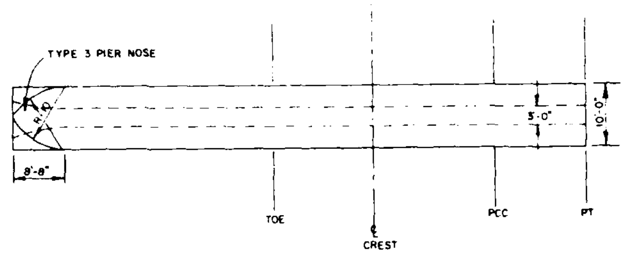
SHEET OF

2



SPILLWAY AND STILLING BASIN PLAN

SCALE 1"=20'-0"



(GATES NOT SHOWN)

PIER PLAN VIEW

SCALE 1"=10'-0"

SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY D J R
DRAWN BY J M J
CHECKED BY J G M
SUBMITTED BY
APPROVED

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
LAKE DARLING DAM
SPILLWAY AND OUTLET WORKS DETAILS

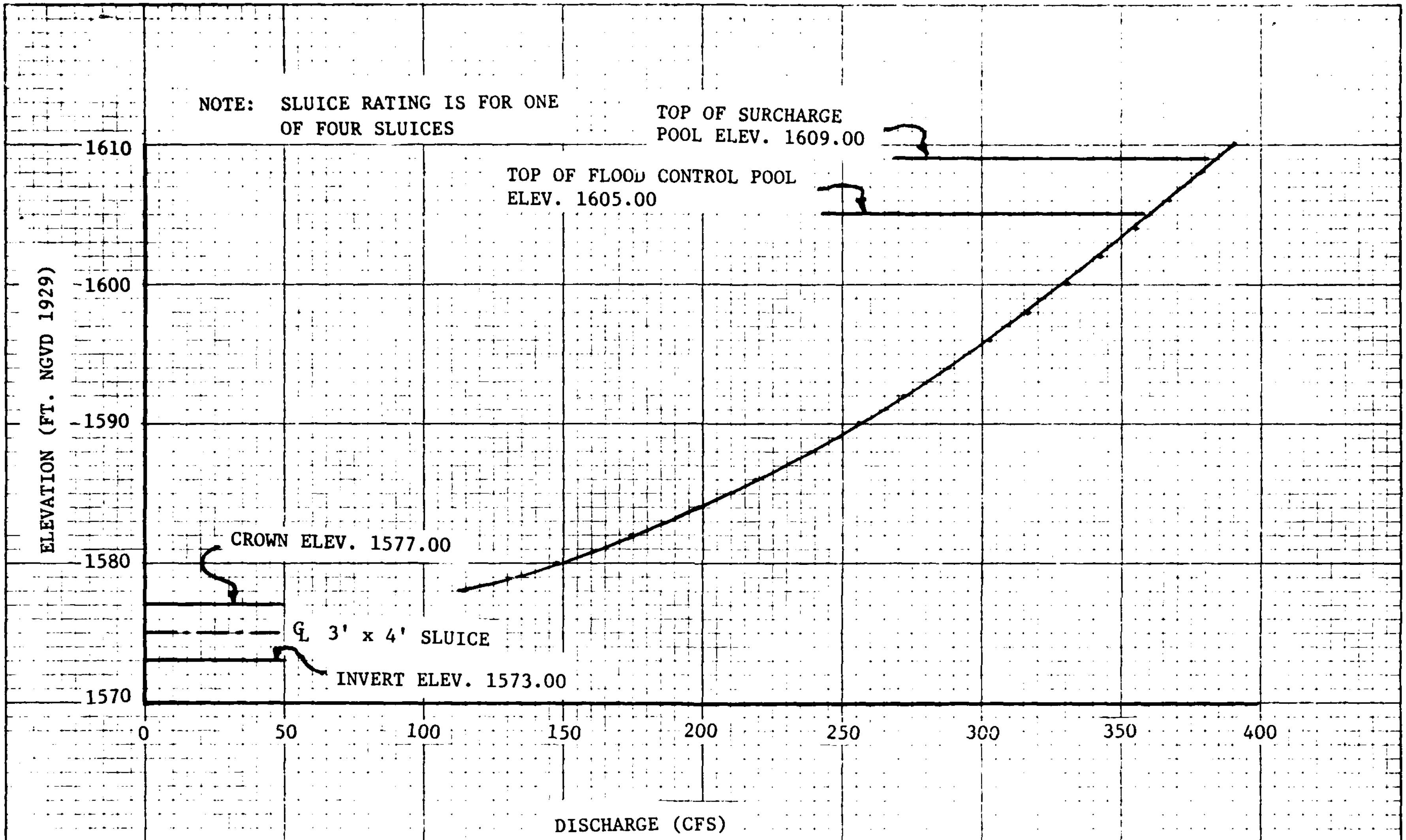
DATE JUNE 1983

SCALE AS SHOWN

DRAWING NUMBER R-RI-5/786

SHEET

1 2



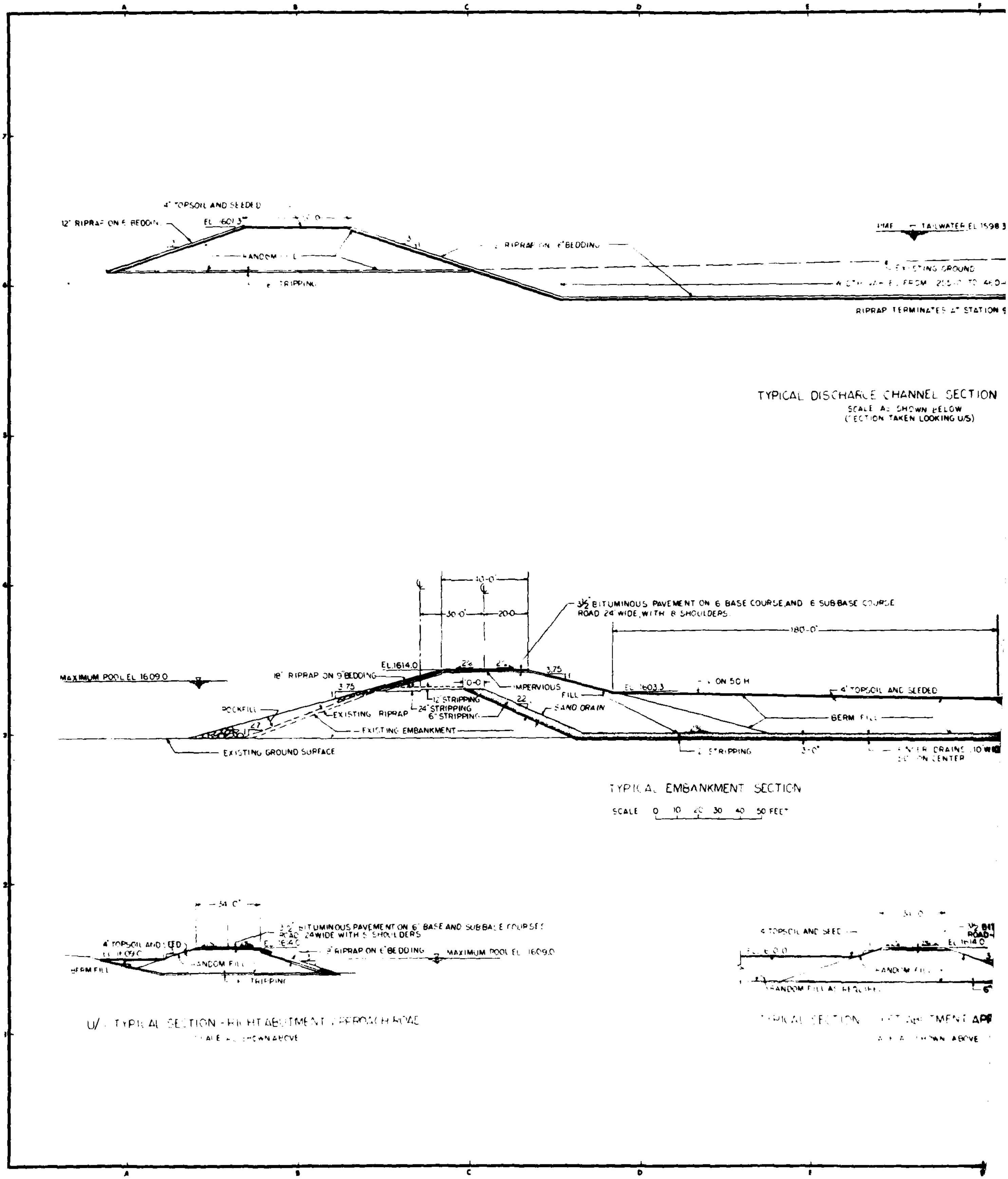
DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

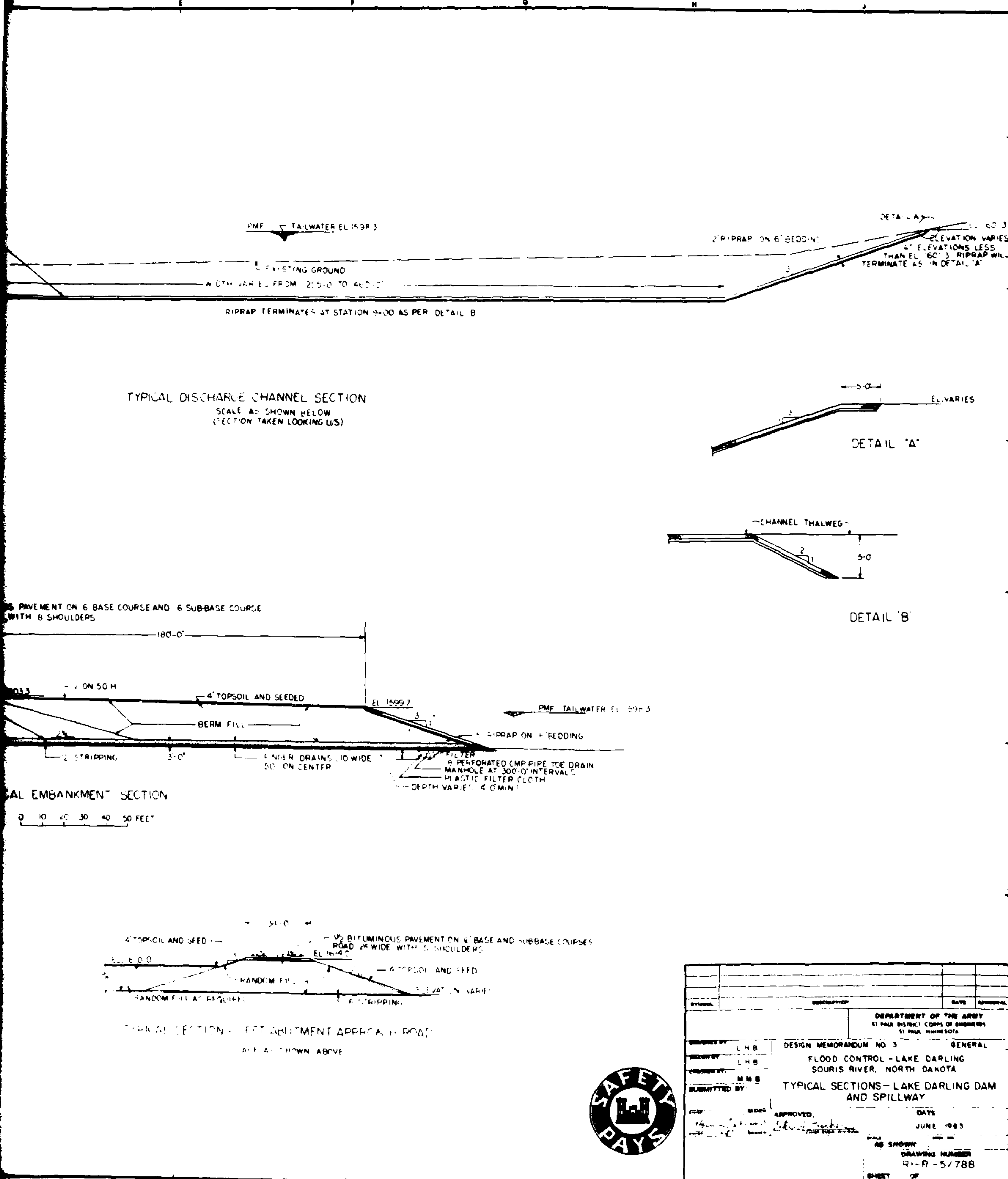
SLUICE RATING CURVE

St. Paul District, Corps of Engineers

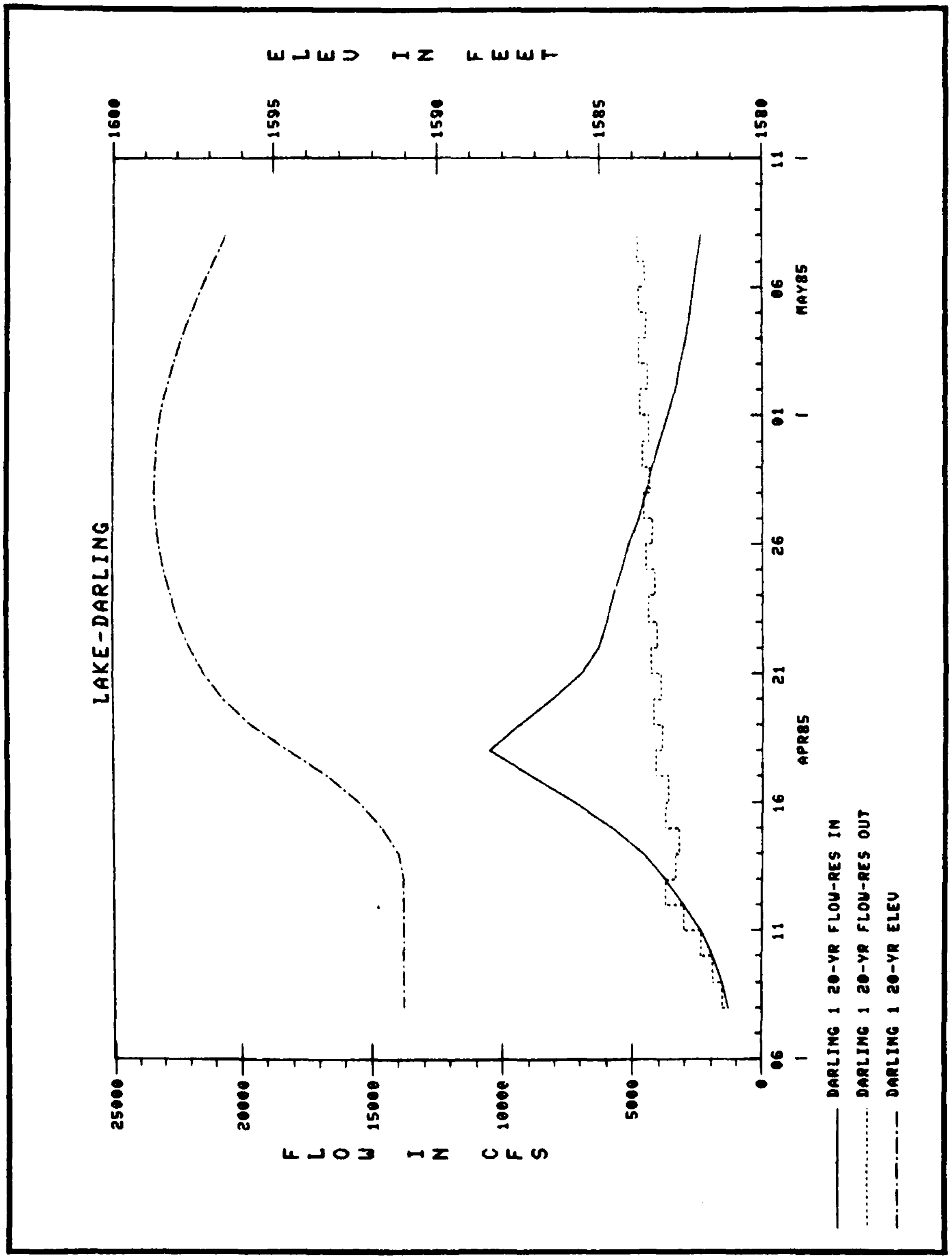
FILE NO. R1-R-5/ 787 June 1983



4" TOPSOIL AND SEEDED
12" RIPRAP ON 6" BEDDING
EL 1601.3
RANDOM FILL
RIPRAP ON 6" BEDDING
STRIPPING
TAILWATER EL 1598.3
EXISTING GROUND
RIPRAP TERMINATES AT STATION
TYPICAL DISCHARGE CHANNEL SECTION
SCALE AS SHOWN BELOW
(SECTION TAKEN LOOKING U/S)
40'-0"
30'-0"
20'-0"
3½" BITUMINOUS PAVEMENT ON 6" BASE COURSE AND 6" SUBBASE COURSE
ROAD 24' WIDE, WITH 8' SHOULDERS
180'-0"
MAXIMUM POOL EL 1609.0
18" RIPRAP ON 9" BEDDING
EL 1614.0
3.75
10'-0"
IMPERVIOUS
FILL
EL 1603.3
ON 50 H
4" TOPSOIL AND SEEDED
ROCKFILL
EXISTING RIPRAP
12" STRIPPING
24" STRIPPING
6" STRIPPING
SAND DRAIN
BERM FILL
EXISTING EMBANKMENT
EXISTING GROUND SURFACE
STRIPPING
TYPICAL EMBANKMENT SECTION
SCALE 0 10 20 30 40 50 FEET
34'-0"
3½" BITUMINOUS PAVEMENT ON 6" BASE AND SUBBASE COURSES
ROAD 24' WIDE WITH 5' SHOULDERS
4" TOPSOIL AND SEED
RANDOM FILL
BERM FILL
RIPRAP ON 6" BEDDING
MAXIMUM POOL EL 1609.0
STRIPPING
U/S TYPICAL SECTION - RIGHT ABUTMENT APPROACH ROAD
SCALE AS SHOWN ABOVE
4" TOPSOIL AND SEED
EL 1614.0
RANDOM FILL
RANDOM FILL AS REQUIRED
TYPICAL SECTION - LEFT ABUTMENT APP
AS SHOWN ABOVE

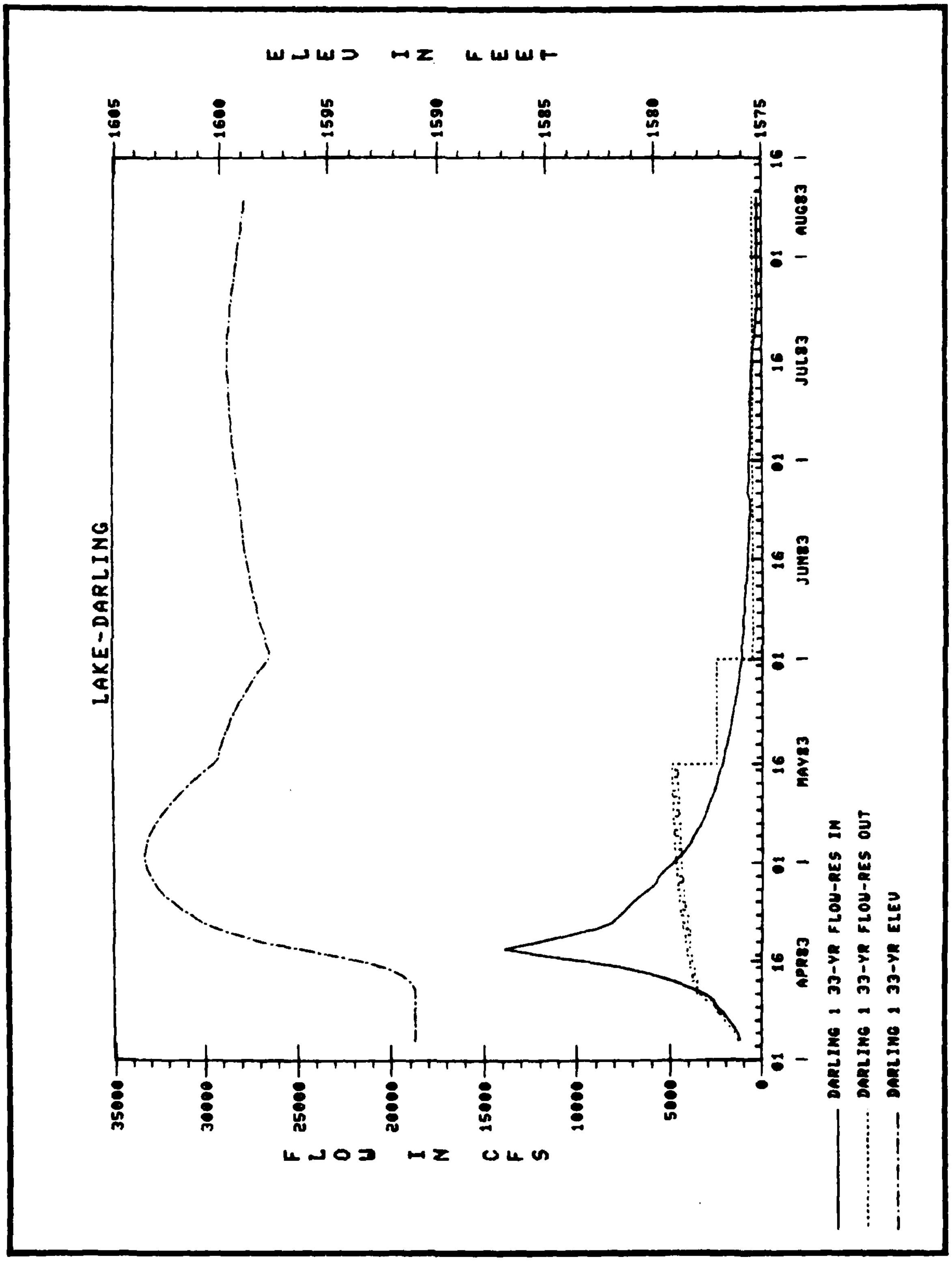

PMF TAILWATER EL 1598.3
2' RIPRAP ON 6" BEDDING
DETAIL A
EL 1601.3
ELEVATION VARIES
AT ELEVATIONS LESS THAN EL 1601.3 RIPRAP WILL TERMINATE AS IN DETAIL "A"
EXISTING GROUND
WIDTH VARIES FROM 225'-0" TO 460'-0"
RIPRAP TERMINATES AT STATION 9+00 AS PER DETAIL B
TYPICAL DISCHARGE CHANNEL SECTION
SCALE AS SHOWN BELOW
(SECTION TAKEN LOOKING U/S)
5'-0"
EL VARIES
DETAIL "A"
CHANNEL THALWEG
5'-0"
DETAIL "B"
PAVEMENT ON 6" BASE COURSE AND 6" SUBBASE COURSE WITH 8' SHOULDERS
180'-0"
1 V ON 50 H
4" TOPSOIL AND SEEDED
EL 1599.7
PMF TAILWATER EL 1598.3
BERM FILL
RIPRAP ON 6" BEDDING
2' STRIPPING
3'-0"
FINGER DRAINS 10' WIDE 50' ON CENTER
FILTER
6" PERFORATED CMP PIPE TOE DRAIN
MANHOLE AT 300'-0" INTERVALS
PLASTIC FILTER CLOTH
DEPTH VARIES (4'-0" MIN.)
AL EMBANKMENT SECTION
0 10 20 30 40 50 FEET
31'-0"
4" TOPSOIL AND SEED
1½" BITUMINOUS PAVEMENT ON 6" BASE AND SUBBASE COURSES ROAD 24' WIDE WITH 3' SHOULDERS
EL 1614.0
4" TOPSOIL AND SEED
RANDOM FILL
RANDOM FILL AS REQUIRED
STRIPPING
ELEVATION VARIES
TYPICAL SECTION - LEFT ABUTMENT APPROACH ROAD
SCALE AS SHOWN ABOVE
SAFETY PAYS
DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT CORPS OF ENGINEERS
ST. PAUL, MINNESOTA
L H B
L H B
M M B
SUBMITTED BY
DESIGN MEMORANDUM NO. 3
GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
TYPICAL SECTIONS - LAKE DARLING DAM AND SPILLWAY
APPROVED
DATE
JUNE 1983
AS SHOWN
DRAWING NUMBER
RI-R-5/788
SHEET OF

1 2



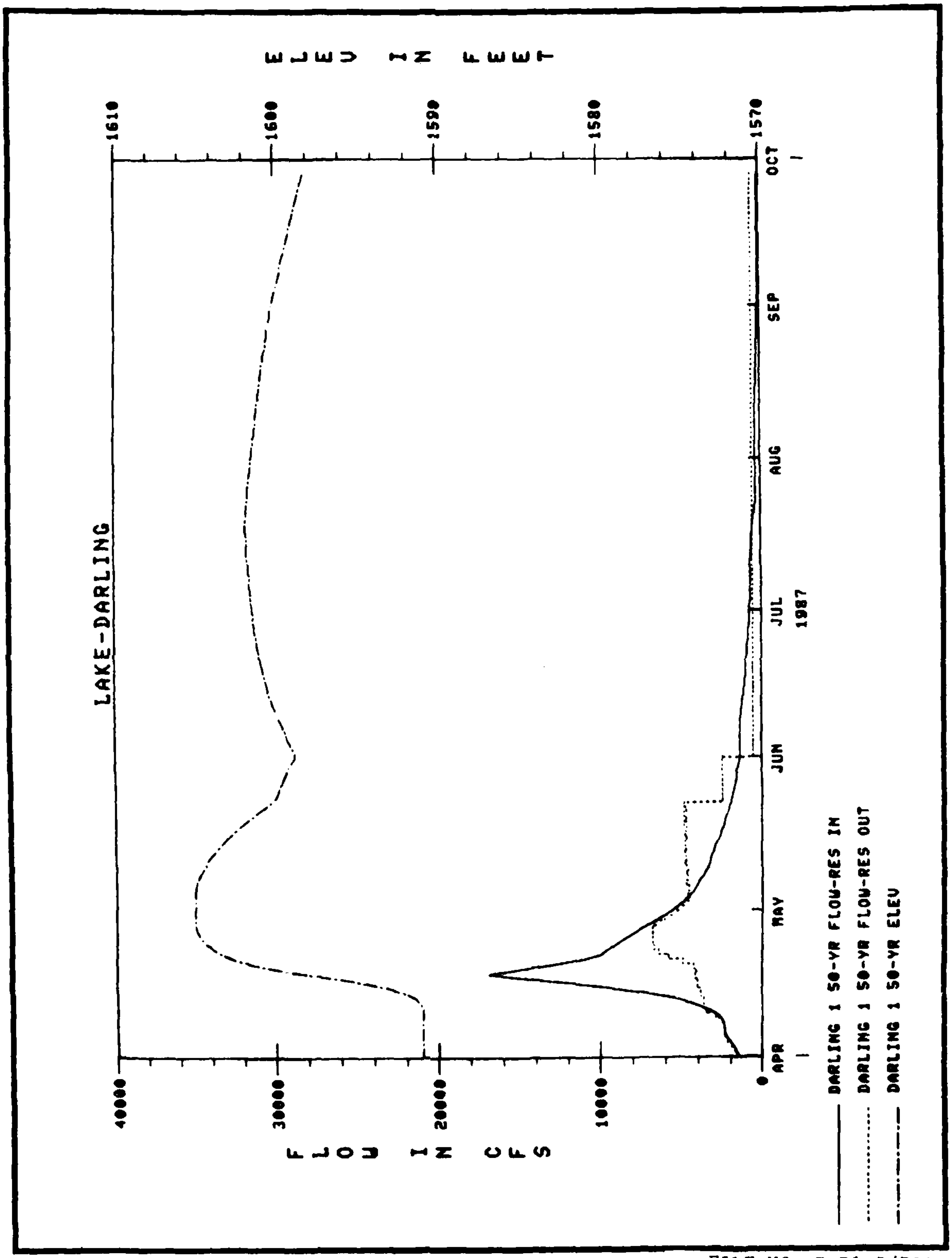
FILE NO. R-R1-5/789

PLATE A-40



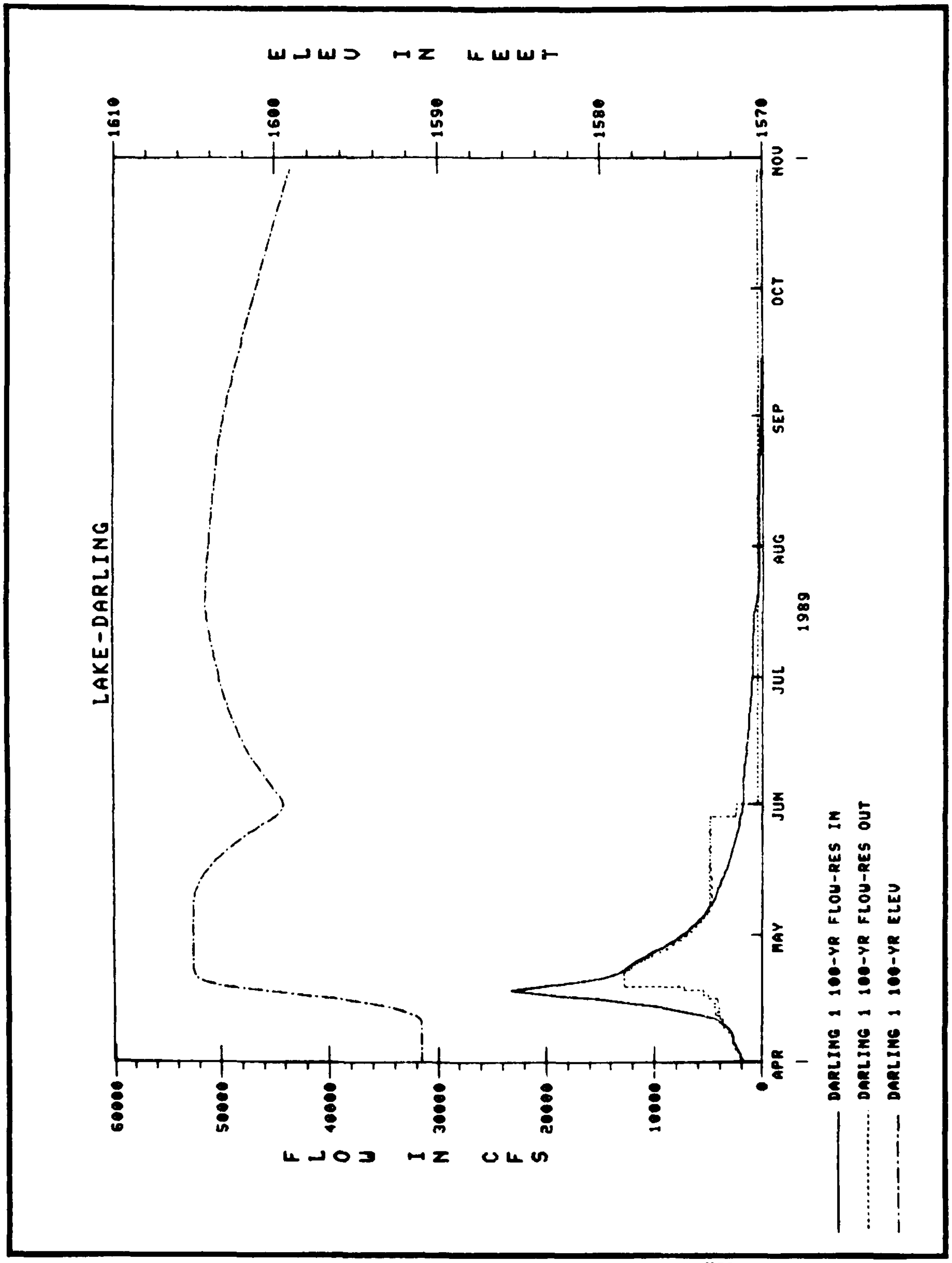
FILE NO. R-R1-5/790

PLATE A-41



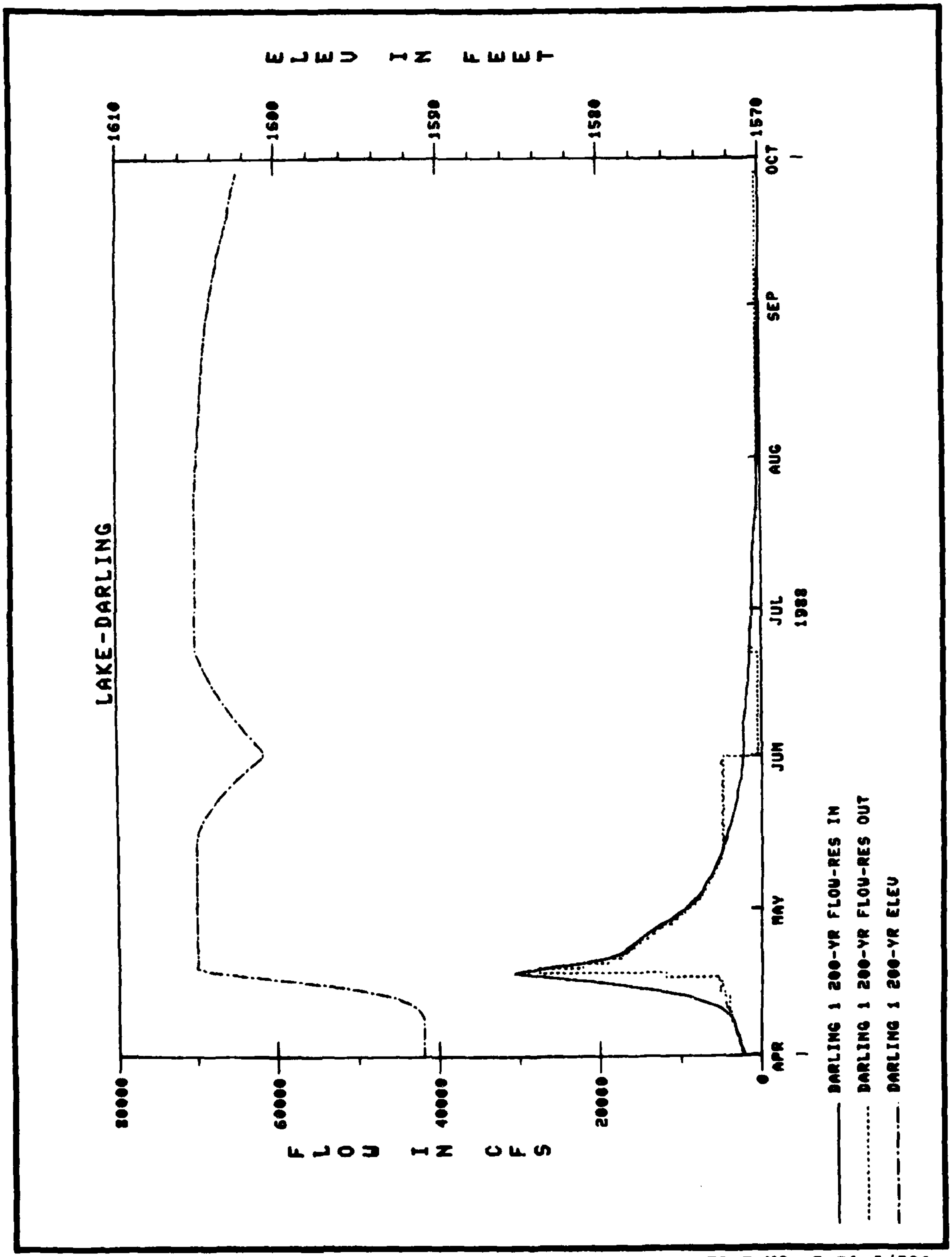
FILE NO. R-R1-5/791

PLATE A-42



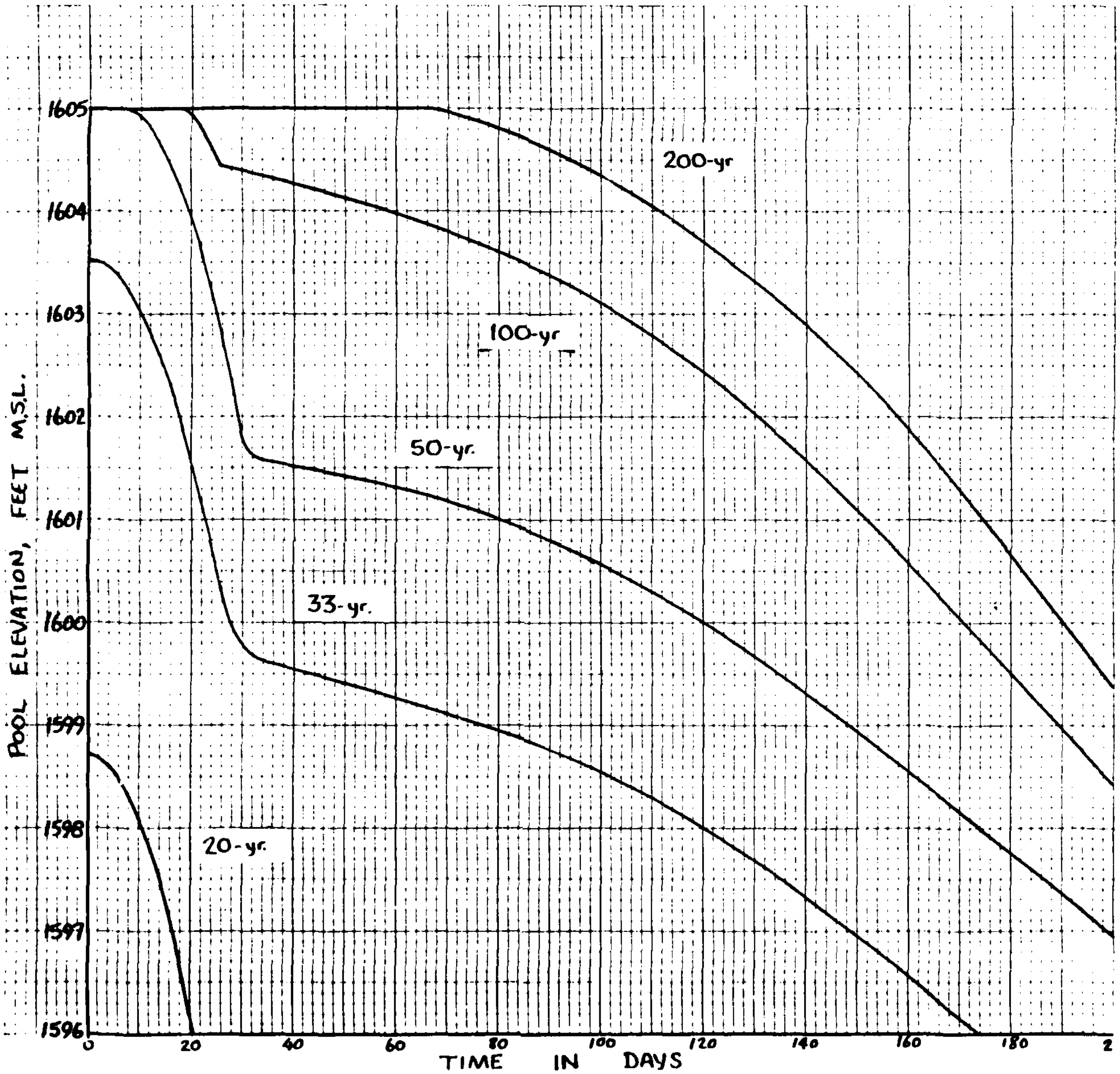
FILE NO. R-R1-5/792

PLATE A-43



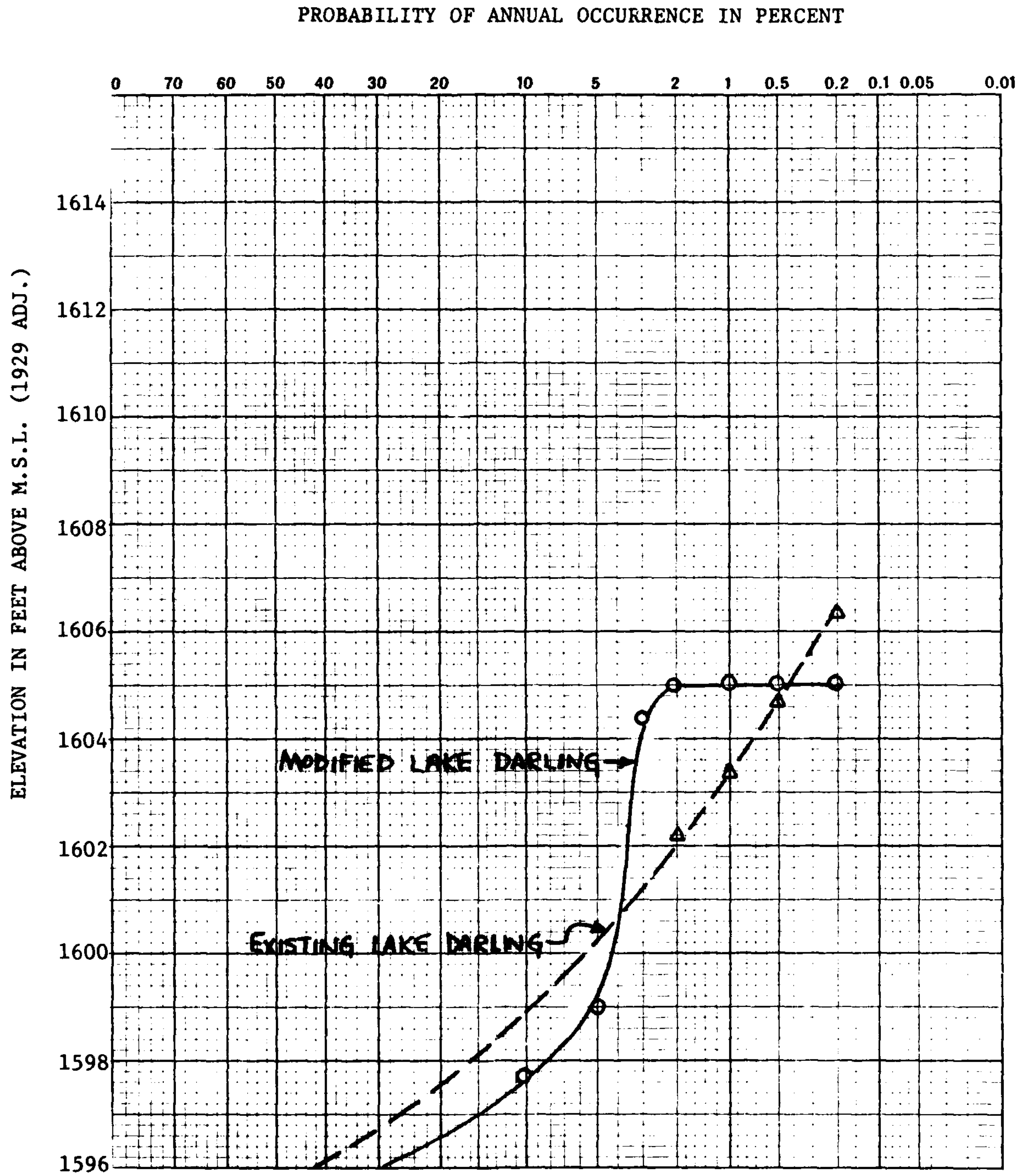
FILE NO. R-R1-5/793

PLATE A-44



FILE NO. R-R1-5/794

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING, ND
Elevation-Duration Frequency Curves
ST. PAUL DISTRICT June 1983



FILE NO. R-R1-5/795

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING, ND
Peak Elevation-Frequency Curve
ST. PAUL DISTRICT June 1983

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL (1 of 13)
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
BANTRY TO TOWNER

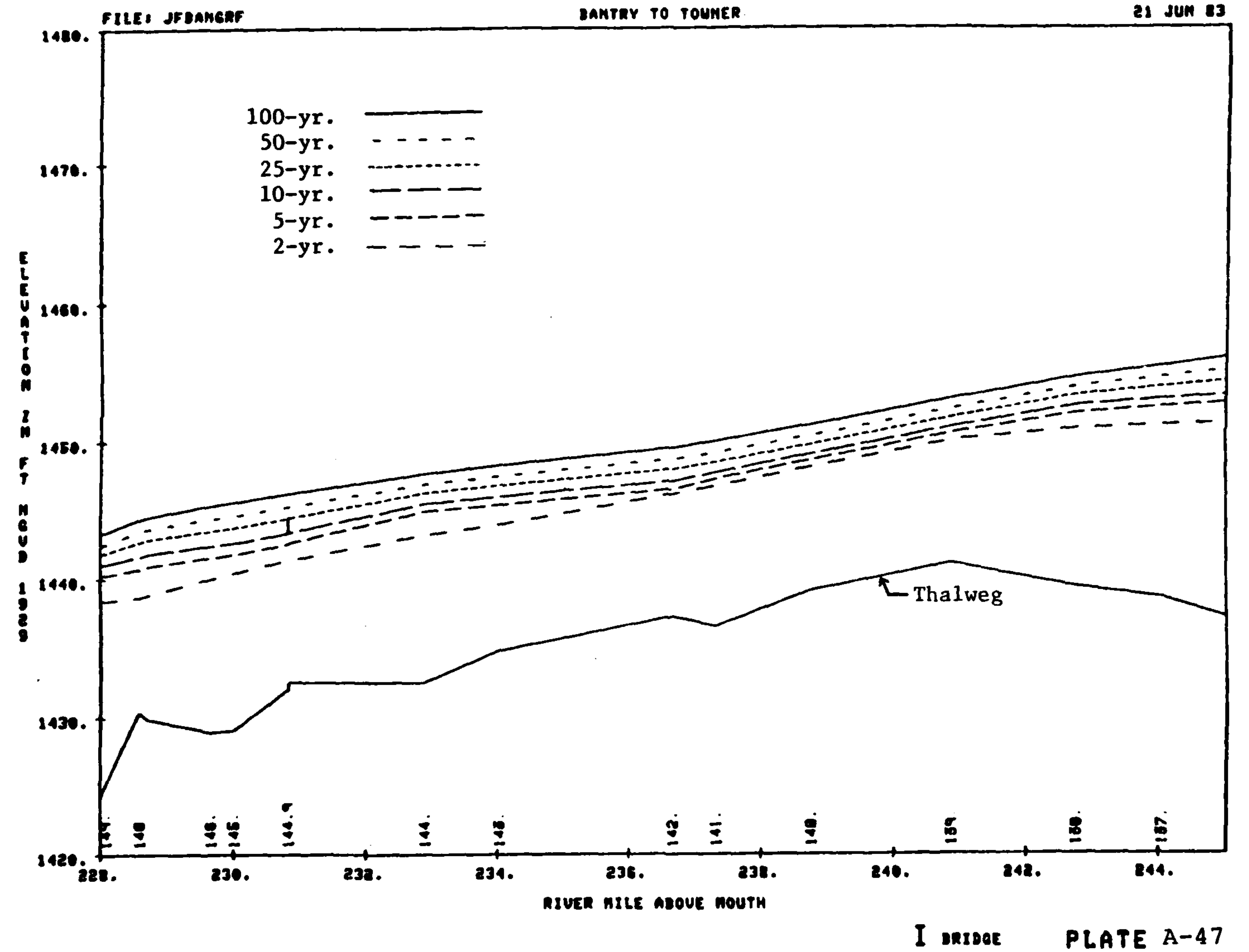
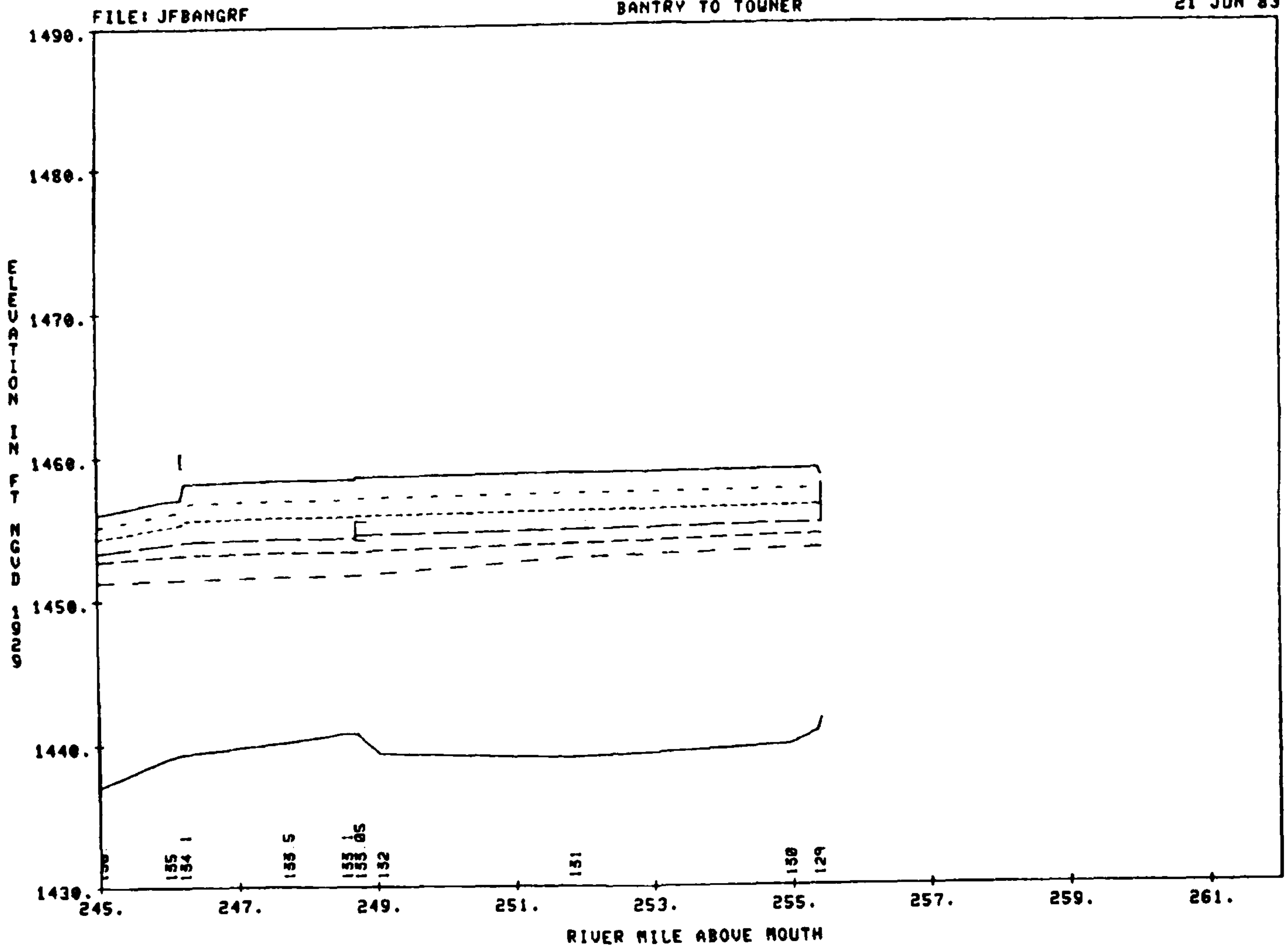


PLATE A-47

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
BANTRY TO TOWNER

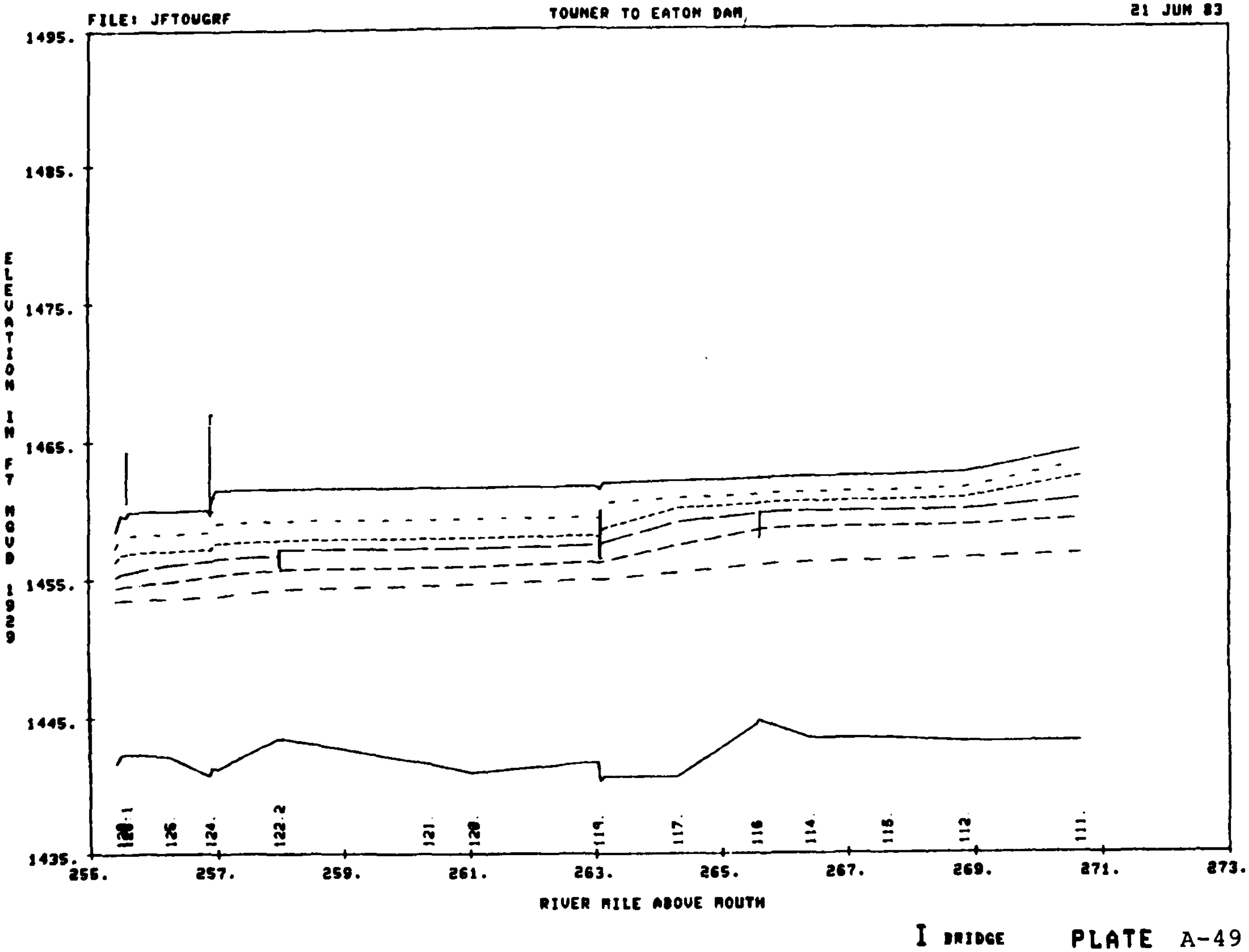
(2 of 13)
21 JUN 83



I BRIDGE

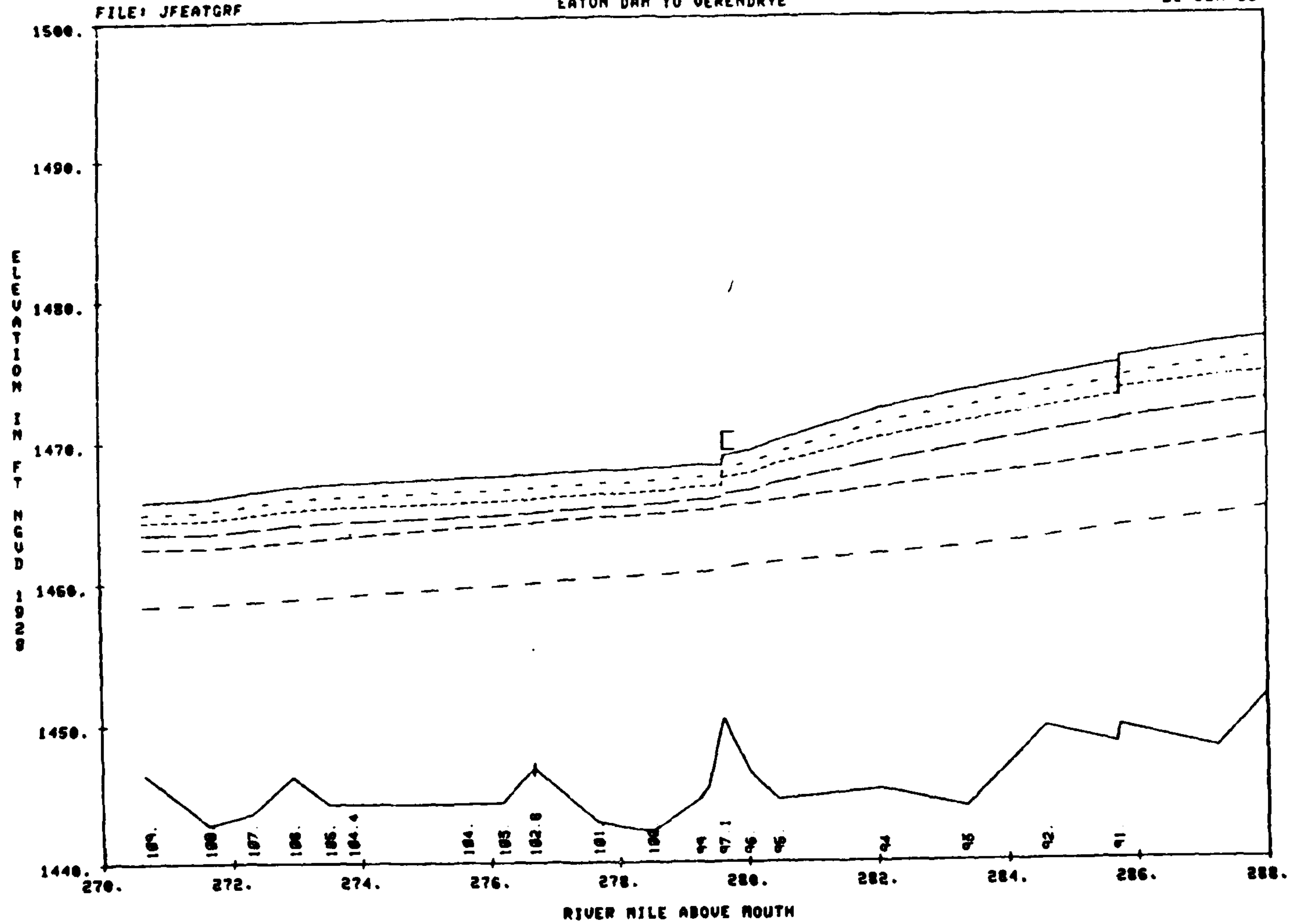
PLATE A-48

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA   DM NO. 3, GENERAL
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
TOWNER TO EATON DAM



LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL (4 of 13)
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
EATON DAM TO VERENDRYE

21 JUN 83



I BRIDGE

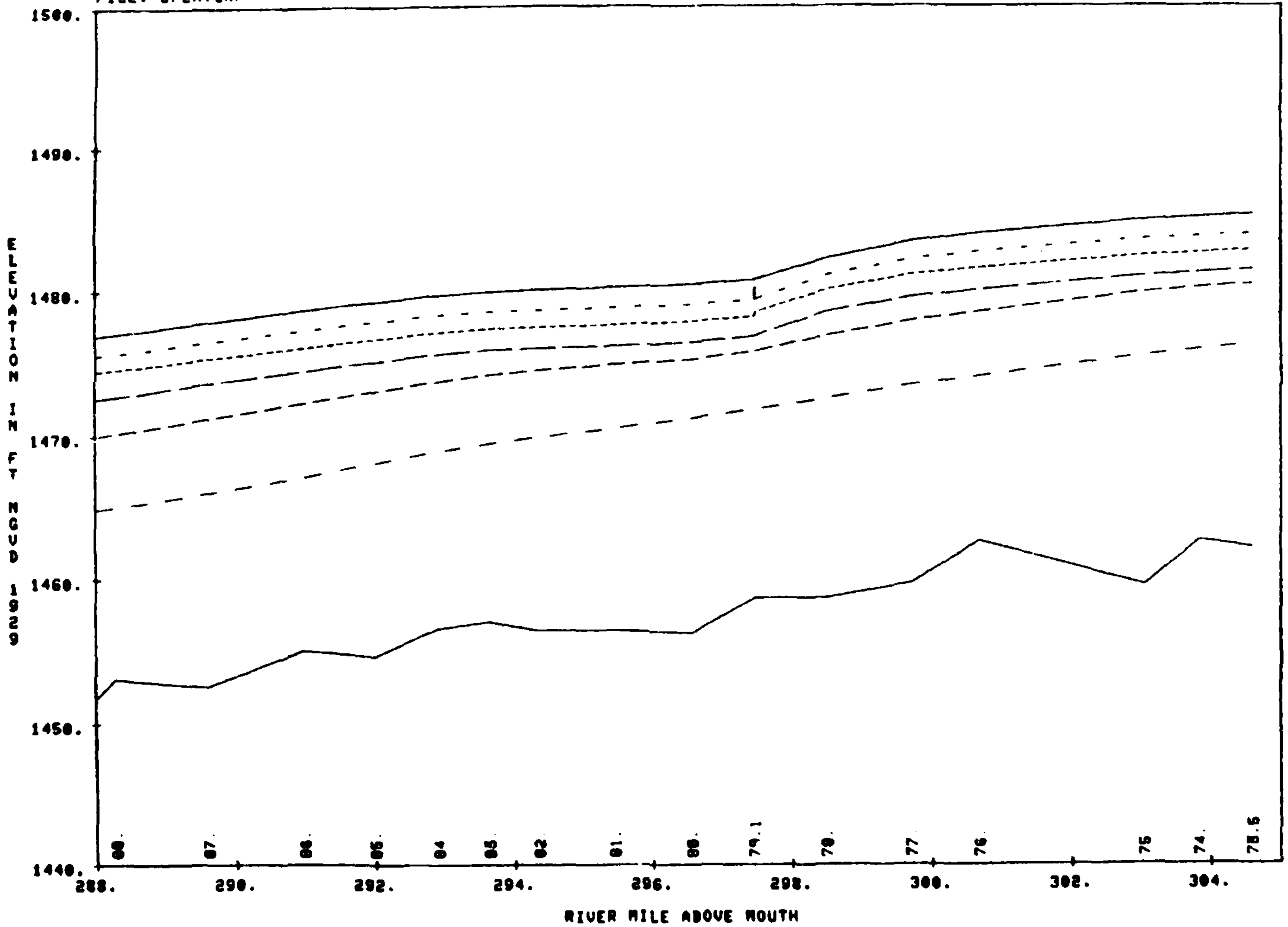
PLATE A-50

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA   DM NO. 3, GENERAL
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
EATON DAM TO VERENDRYE

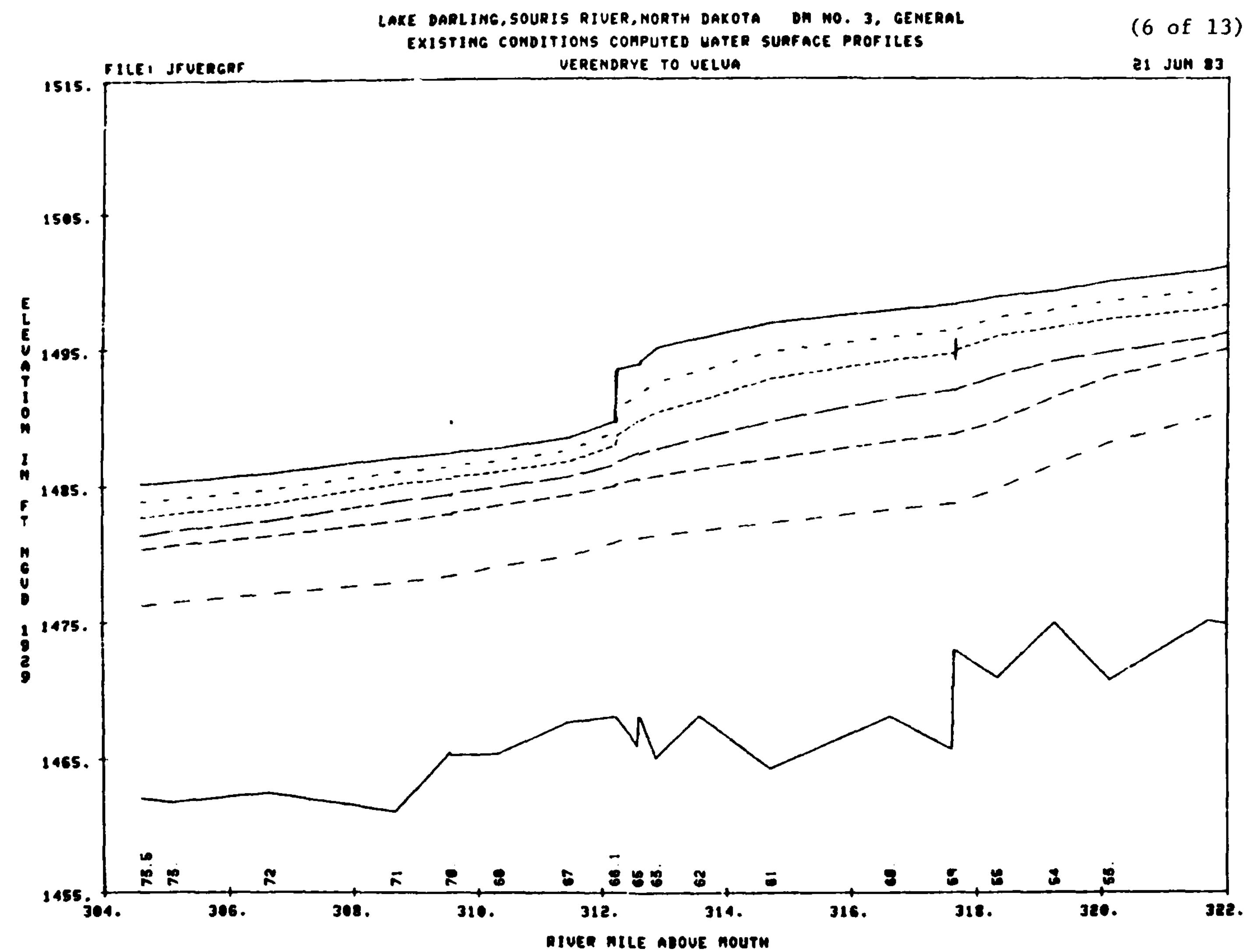
(5 of 13)

FILE: JFEATGRF

21 JUN 83



I BRIDGE


LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
VERENDRYE TO VELVA
(6 of 13)
FILE: JFVERGRF
21 JUN 83
ELEVATION IN FT NGVD 1929
1515.
1505.
1495.
1485.
1475.
1465.
1455.
75.5
78
72
71
70
69
67
66.1
66
65
62
61
60
59
56
54
58
304.
306.
308.
310.
312.
314.
316.
318.
320.
322.
RIVER MILE ABOVE MOUTH
I BRIDGE
PLATE A-52

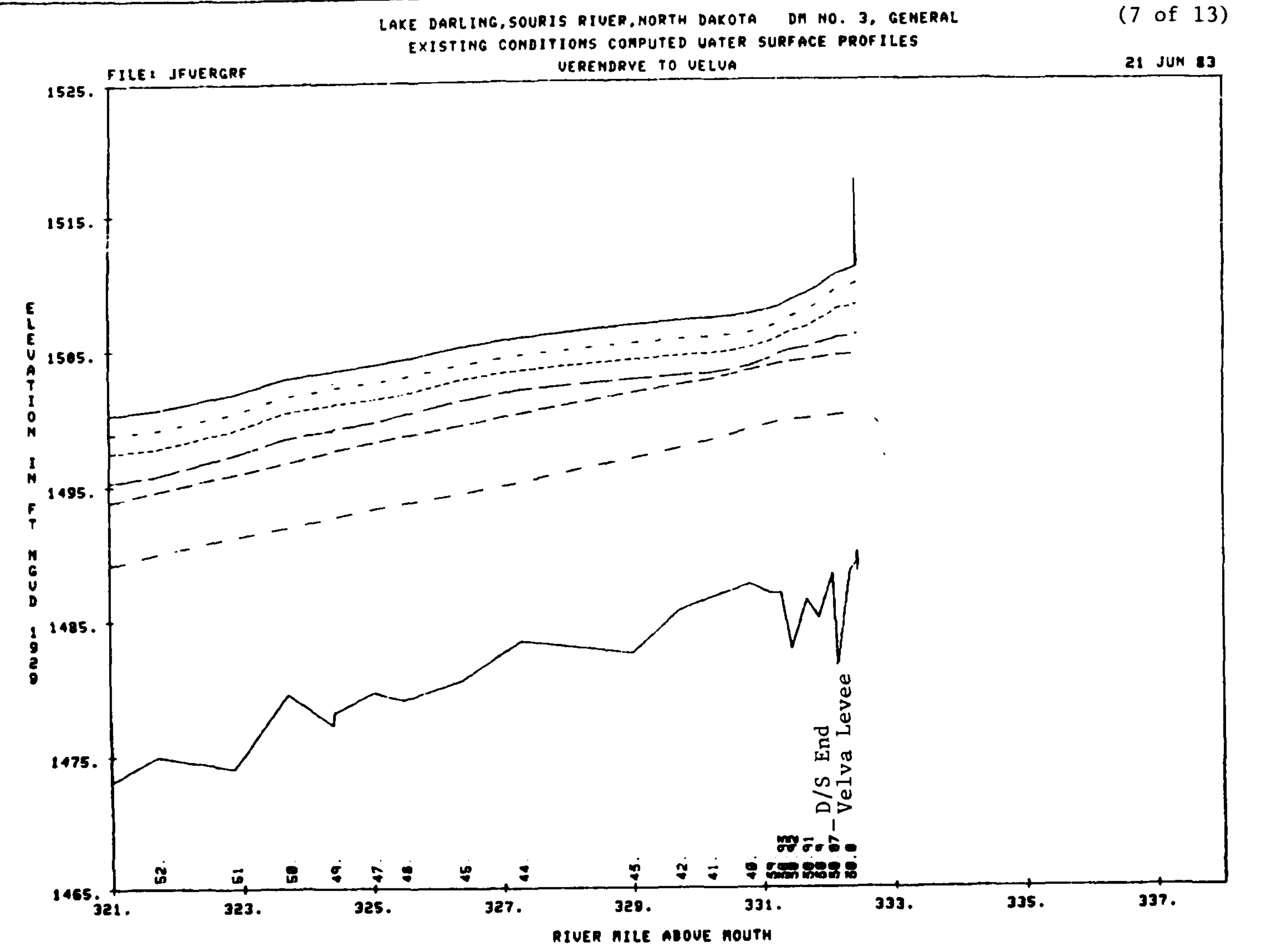

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
VERENDRYE TO VELVA
FILE: JFVERGRF
21 JUN 83
ELEVATION IN FT NGVD 1929
1525.
1515.
1505.
1495.
1485.
1475.
1465.
321.
323.
325.
327.
329.
331.
333.
335.
337.
RIVER MILE ABOVE MOUTH
52
51
50
49
47
46
45
44
45
42
41
40
D/S End
Velva Levee
I BRIDGE

PLATE A-53

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
VELVA TO SAWYER

(8 of 13)

FILE: JFVELGRF 21 JUN 83

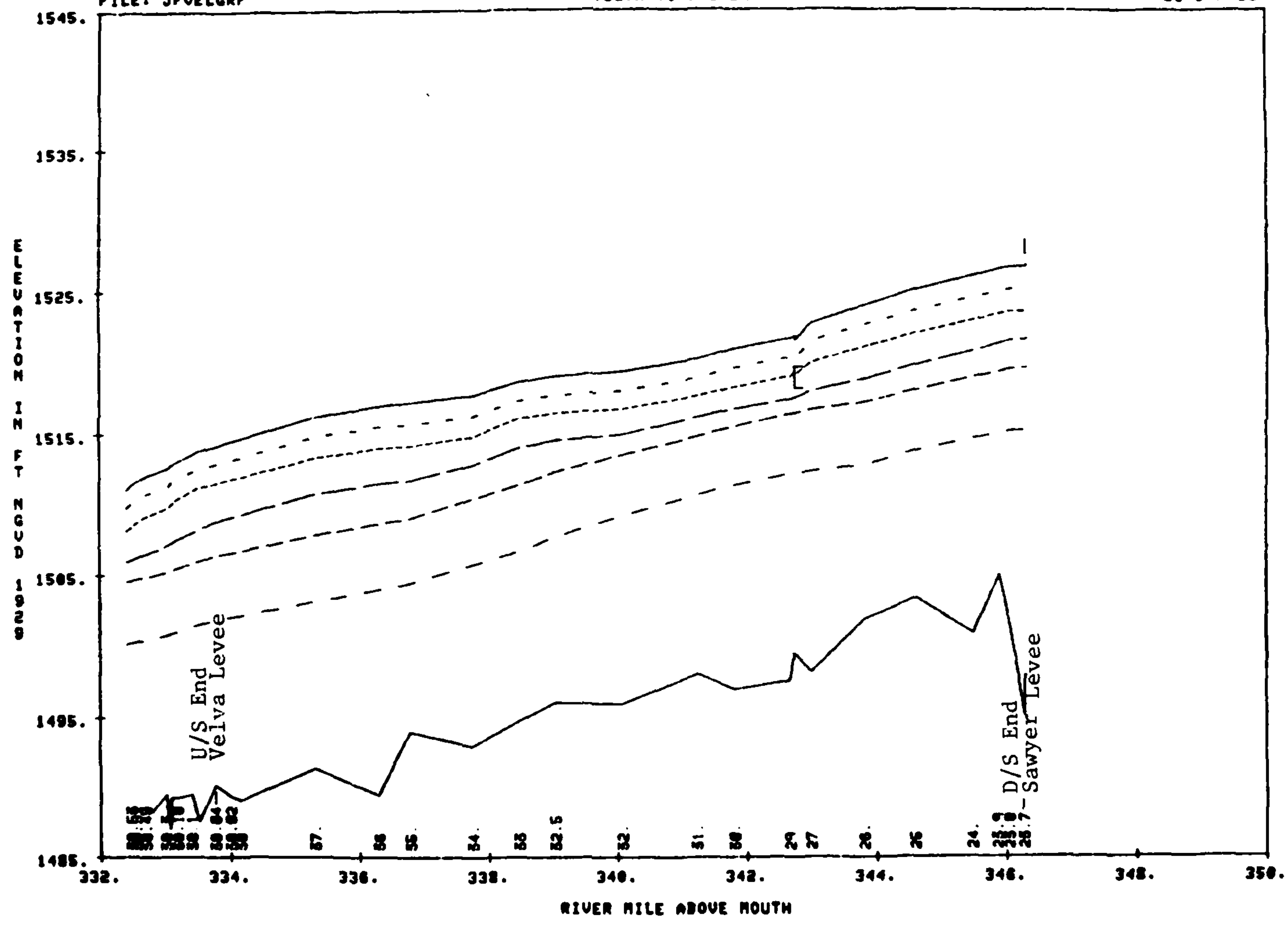
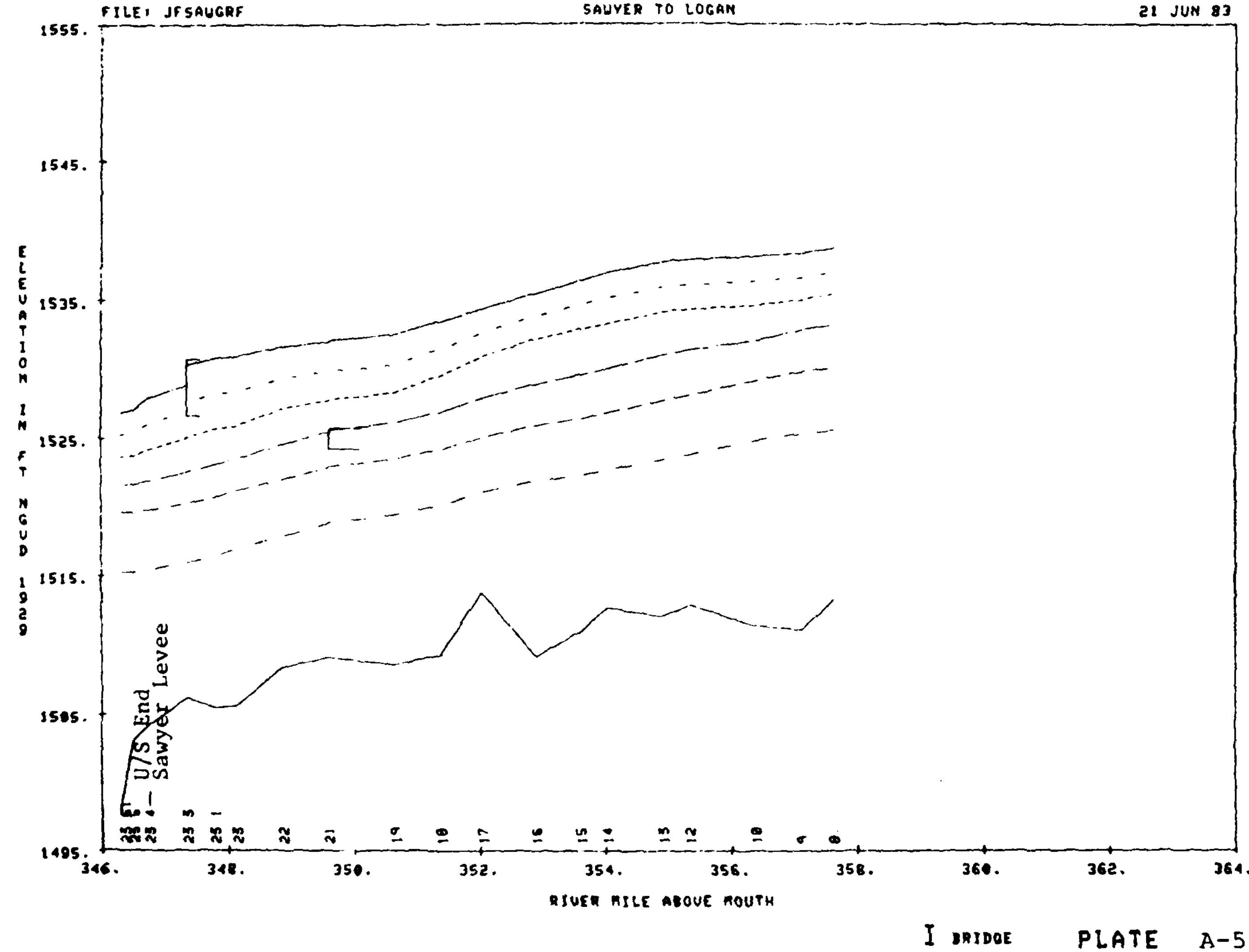


PLATE A-54

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
SAWYER TO LOGAN

FILE: JFSAWGRF

21 JUN 83

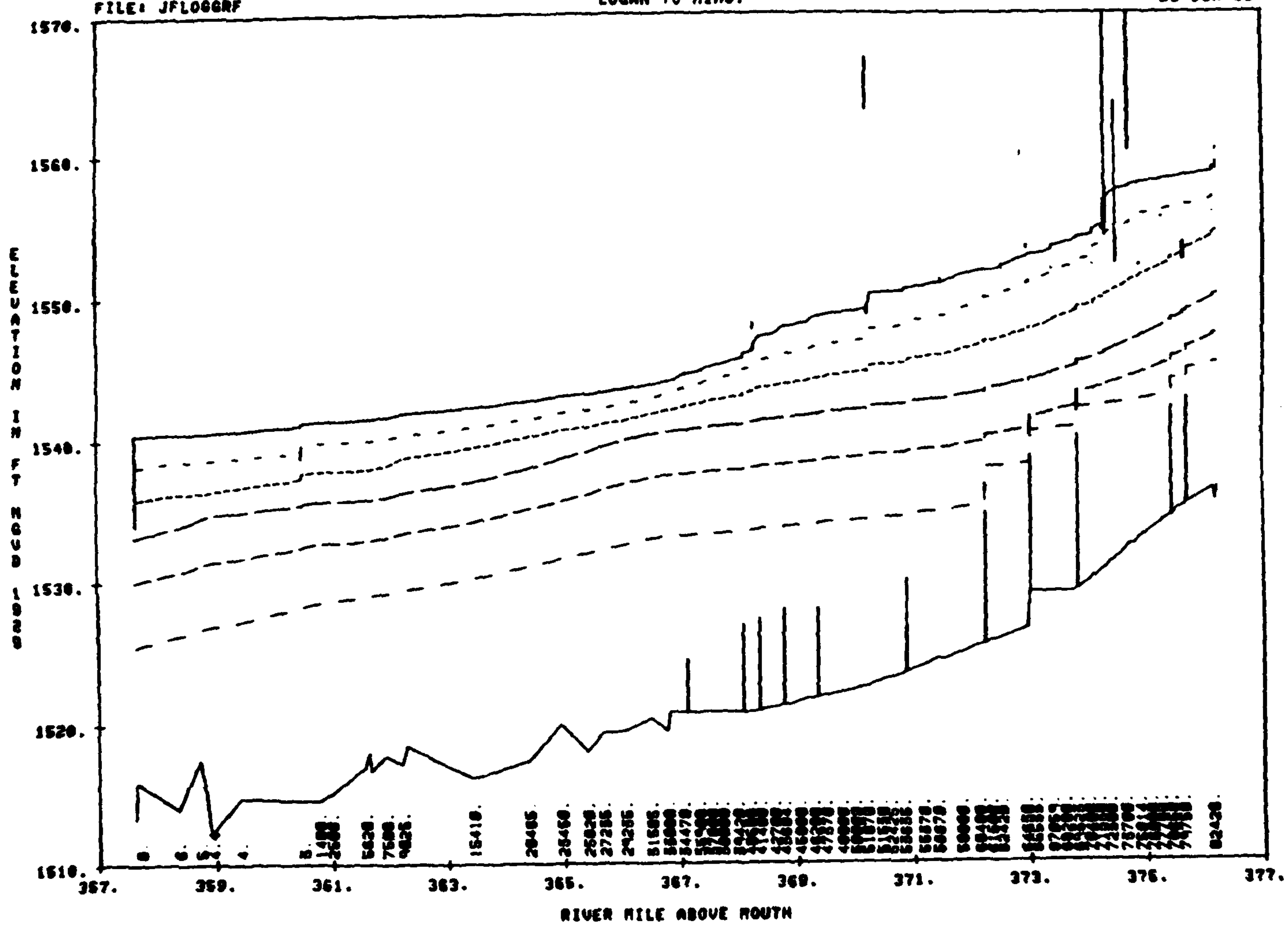


LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
LOGAN TO MINOT

(10 of 13)

FILE: JFLOGGRF

22 JUN 83



I BRIDGE

PLATE A-56

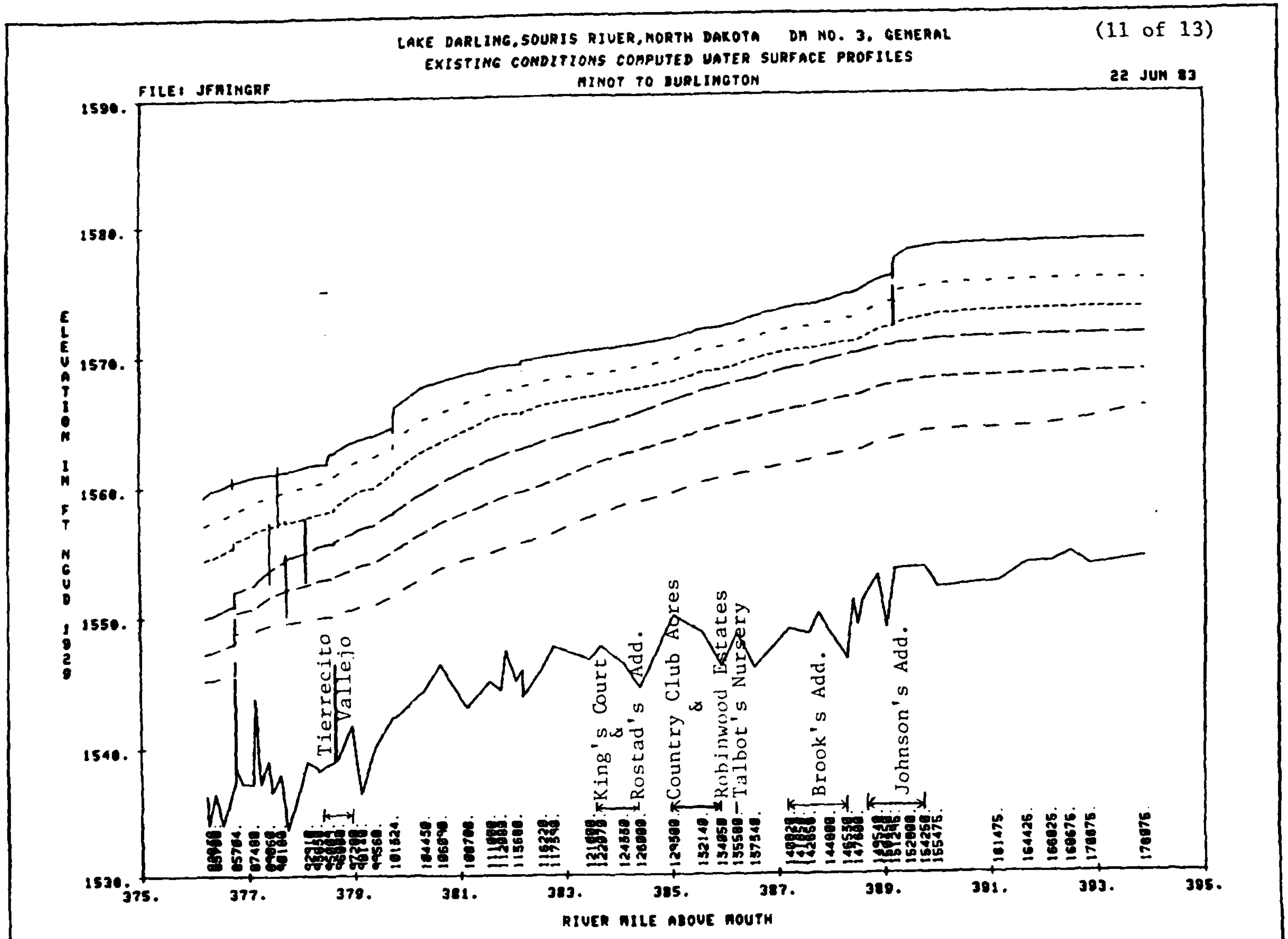

LAKE DARLING,SOURIS RIVER,NORTH DAKOTA DM NO. 3. GENERAL
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
MINOT TO BURLINGTON
(11 of 13)
22 JUN 83
FILE: JFMINGRF
ELEVATION IN FT NGVD 1929
RIVER MILE ABOVE MOUTH
Tierrecito
Vallejo
King's Court
&
Rostad's Add.
Country Club Acres
&
Robinwood Estates
Talbot's Nursery
Brook's Add.
Johnson's Add.
I BRIDGE

PLATE A-57

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA   DM NO. 3, GENERAL
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
BURLINGTON TO LAKE DARLING DAM

FILE: JFBURGRF

22 JUN 83

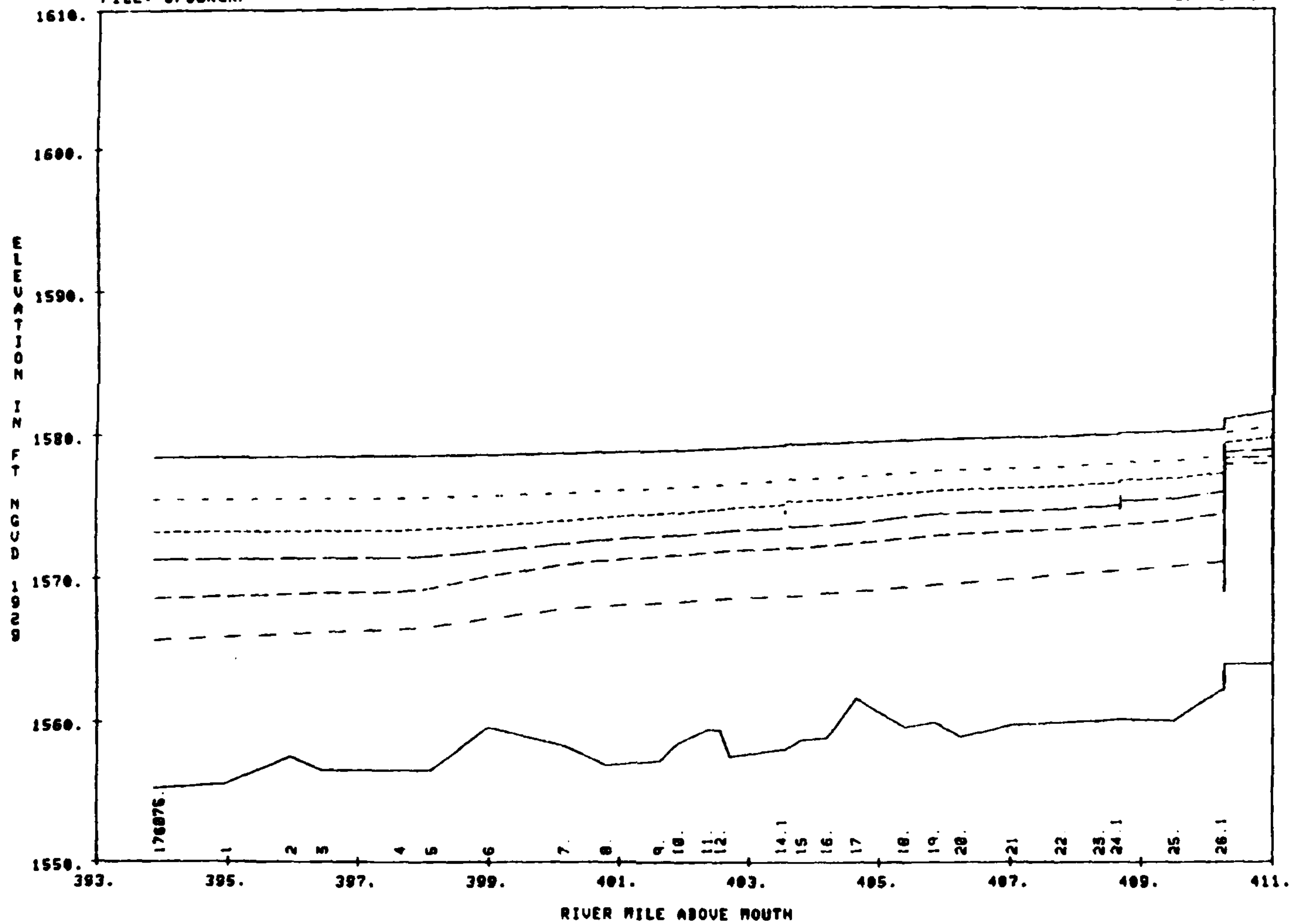
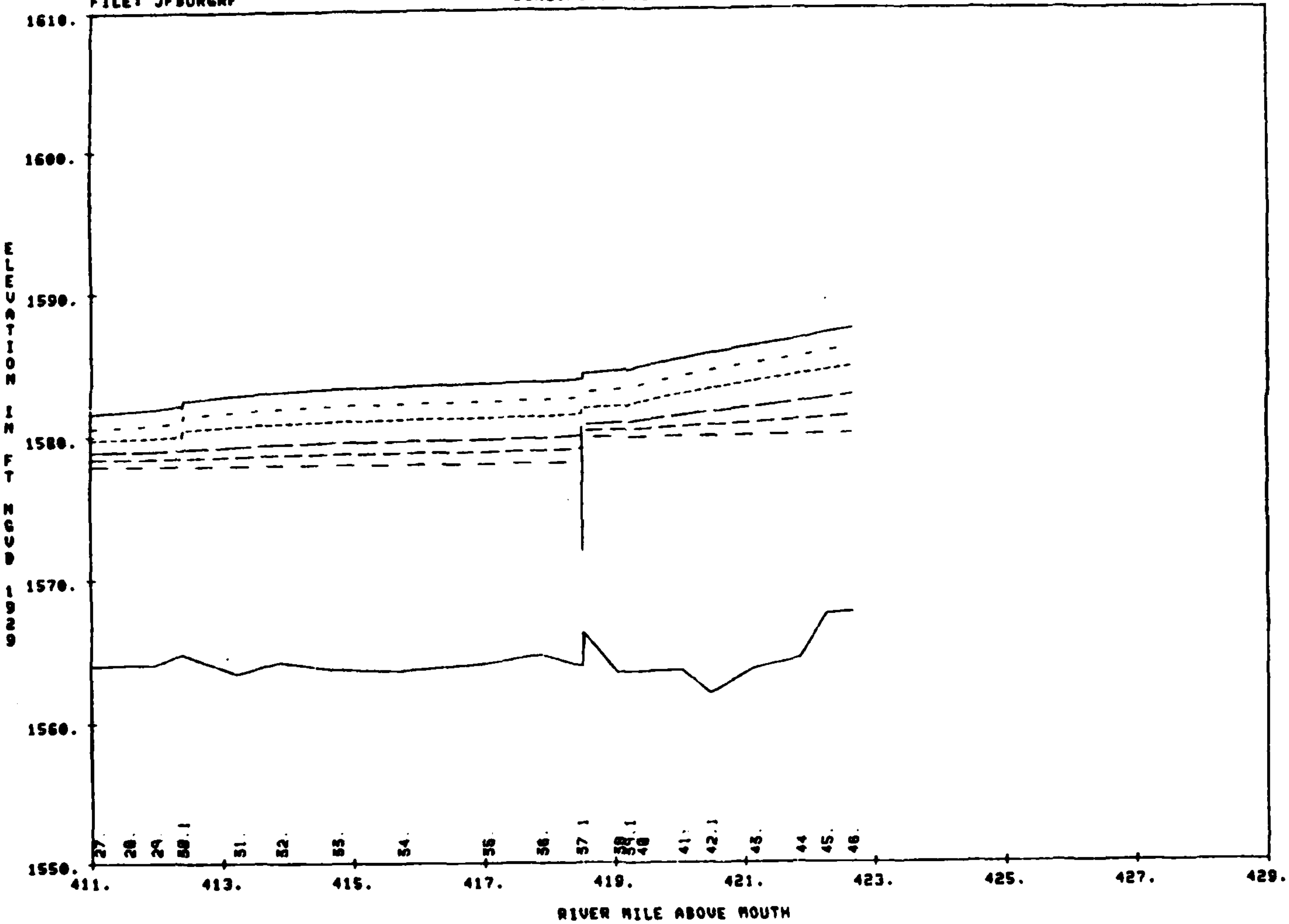


PLATE A-58

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA   DM NO. 3, GENERAL   (13 of 13)
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
BURLINGTON TO LAKE DARLING DAM

FILE: JFBURGRF   22 JUN 83



I BRIDGE

PLATE A-59

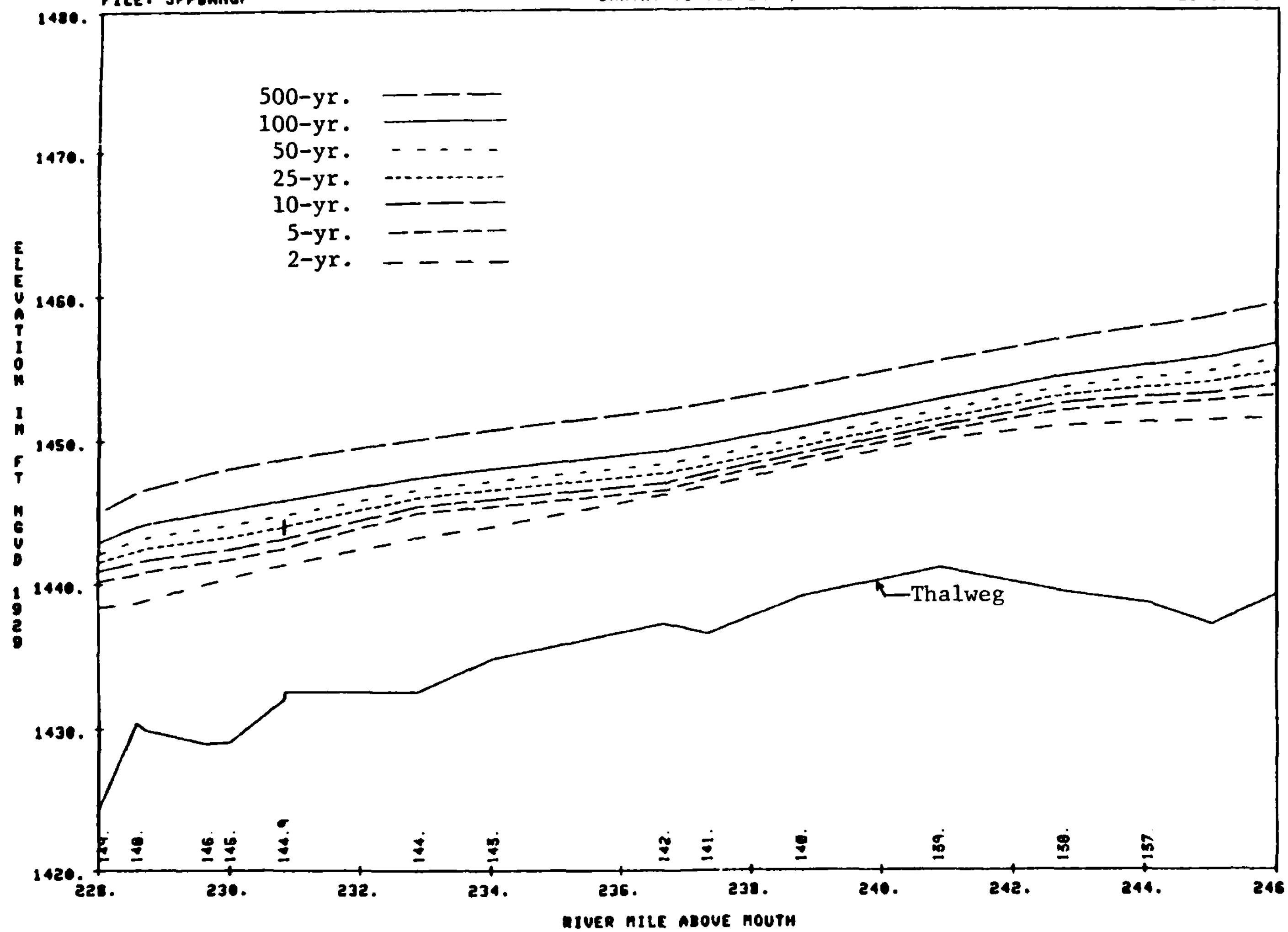
LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL (1 of 13)

PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES

BANTRY TO TOWNER

FILE: JFPBANGF

21 JUN 83



I BRIDGE

PLATE A-60

(2 of 13)

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL
PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES
BANTRY TO TOWNER

21 JUN 83

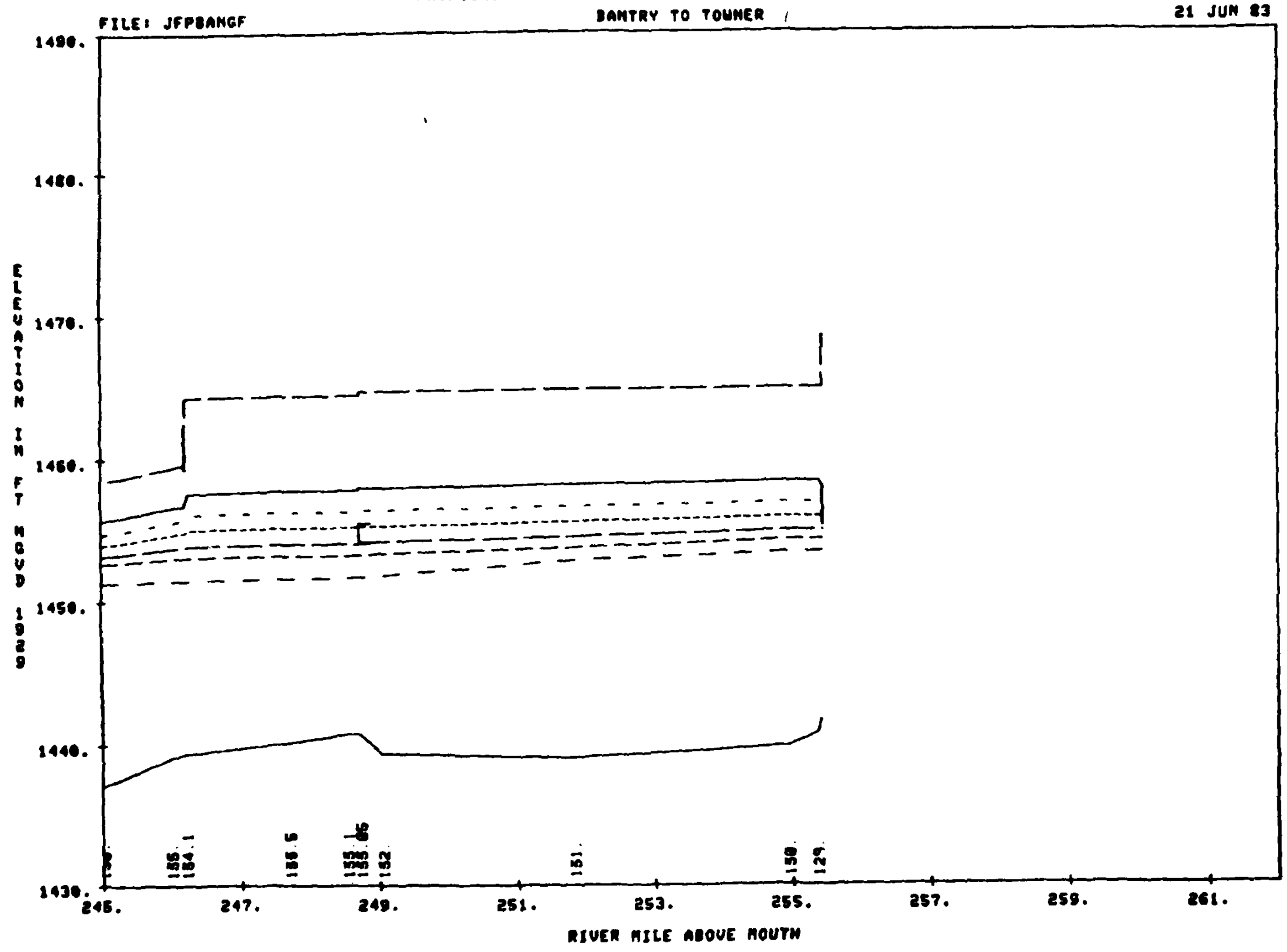


PLATE A-61

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL (4 of 13)
PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES
EATON DAM TO VERENDRYE

FILE: JFPEATGF 21 JUN 83

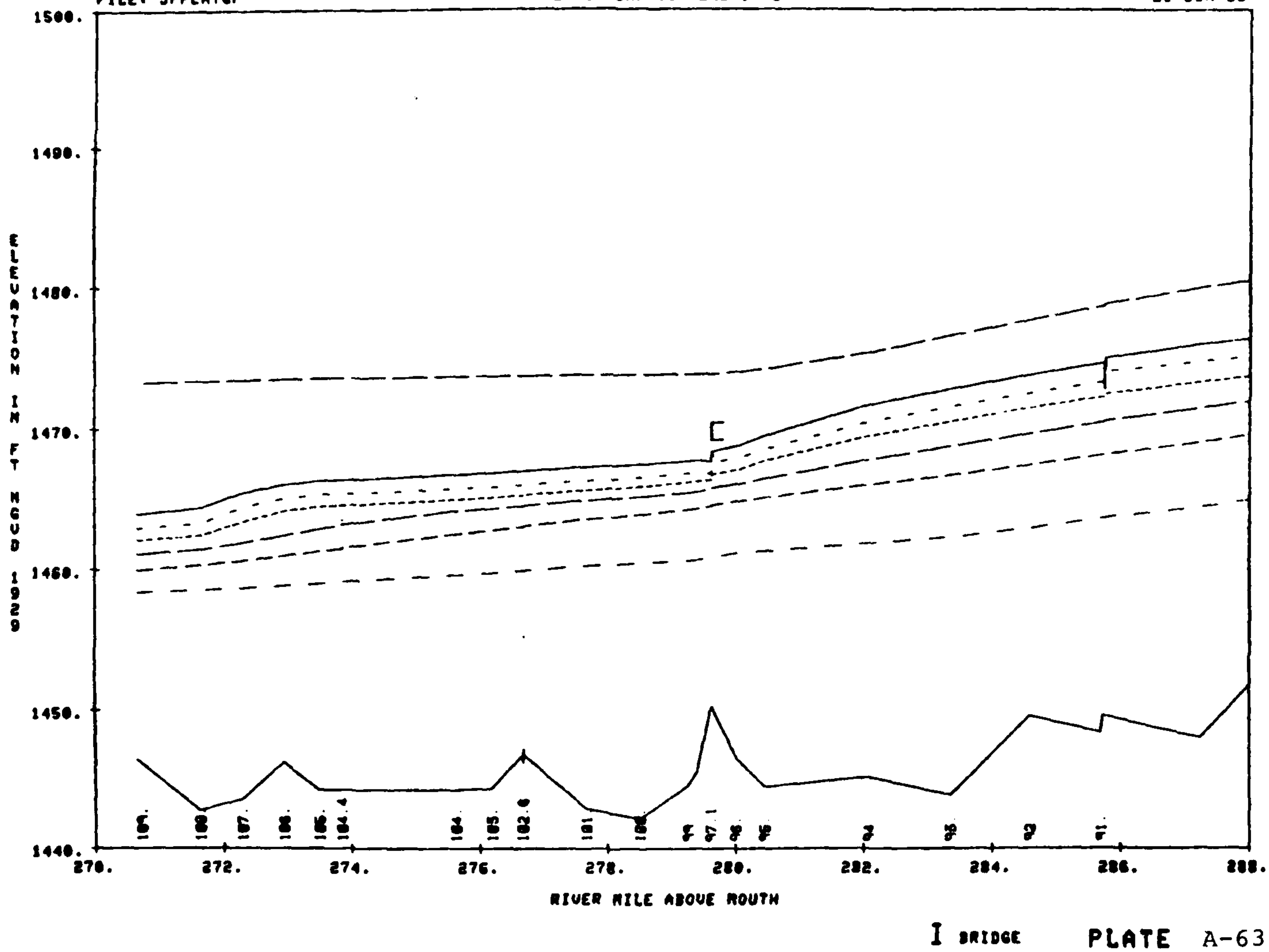
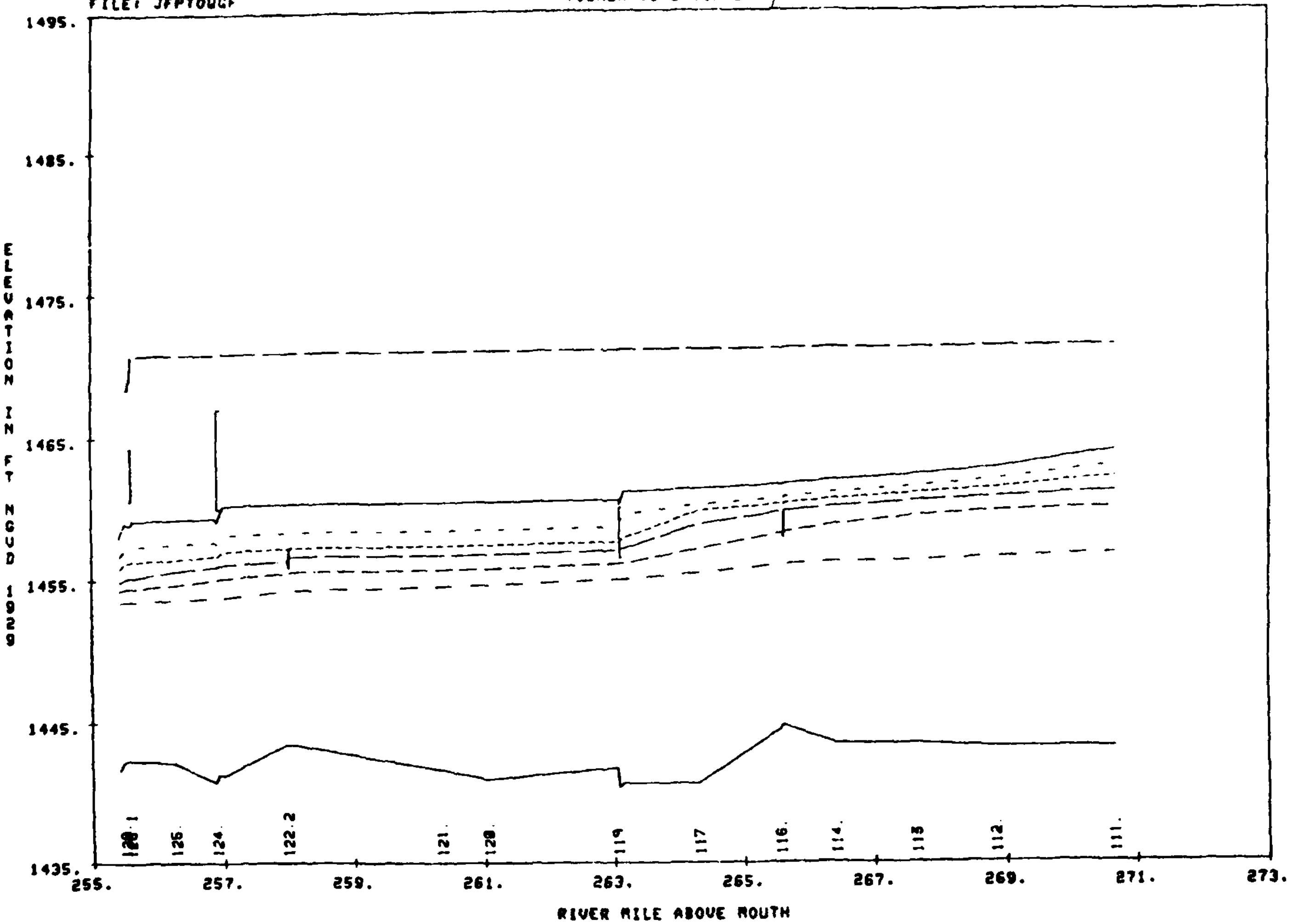


PLATE A-63

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL (3 of 13)
PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES
TOWNER TO EATON DAM

FILE: JFPTOWGF

21 JUN 83



I BRIDGE

PLATE A-62

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA   DM NO. 3, GENERAL

PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES

EATON DAM TO VERENDRYE

FILE: JFPEATGF

21 JUN 83

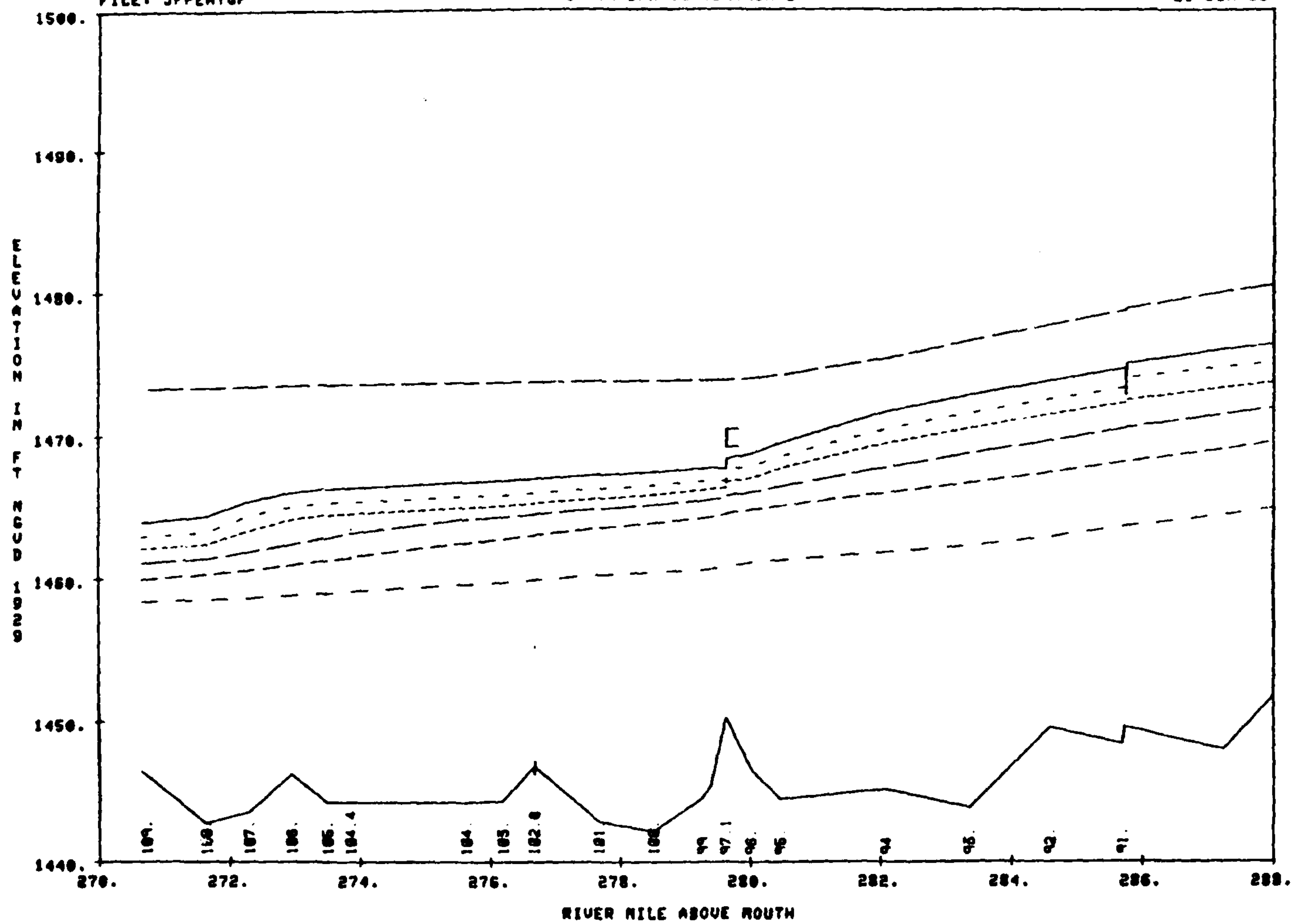


PLATE A-63

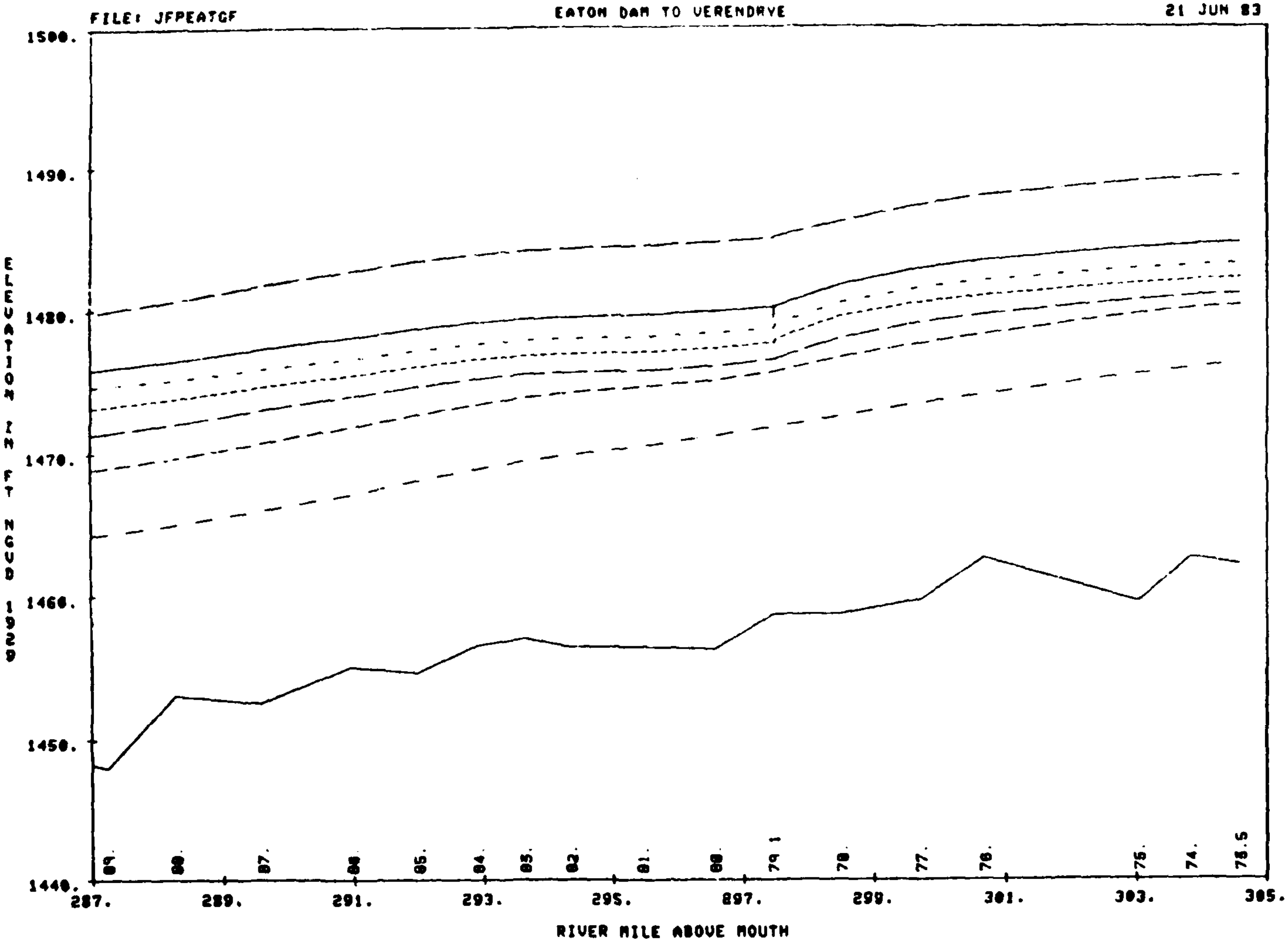
LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL

PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES

EATON DAM TO VERENDRYE

FILE: JFPEATGF

21 JUN 83



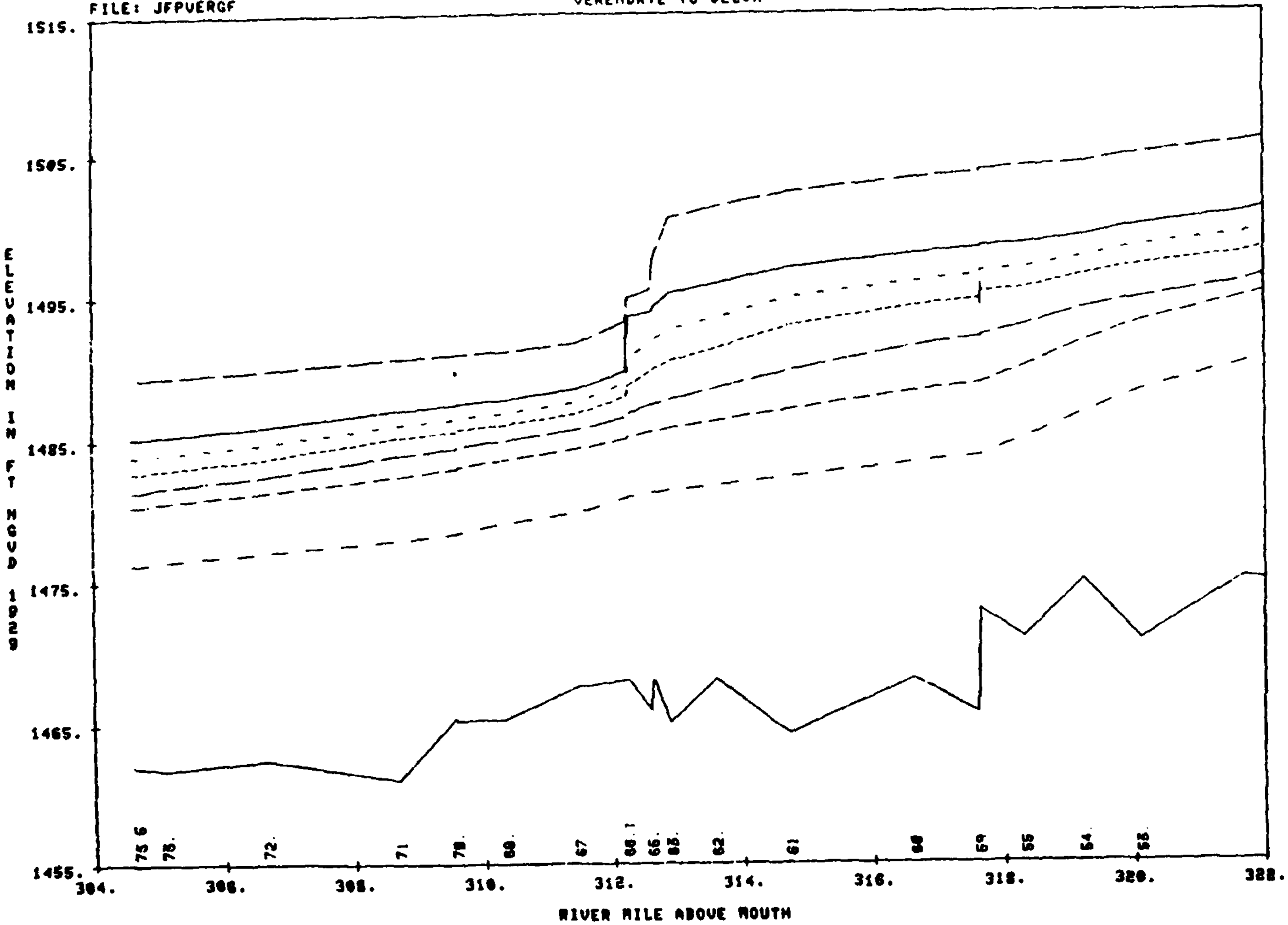
LAKE DARLING, SOURIS RIVER, NORTH DAKOTA   DM NO. 3, GENERAL

PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES

VERENDRYE TO VELVA

21 JUN 83

FILE: JFPVERGF



I BRIDGE

PLATE A-65

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA   DM NO. 3, GENERAL
PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES
VERENDRYE TO VELVA

FILE: JFPVERGF

21 JUN 83

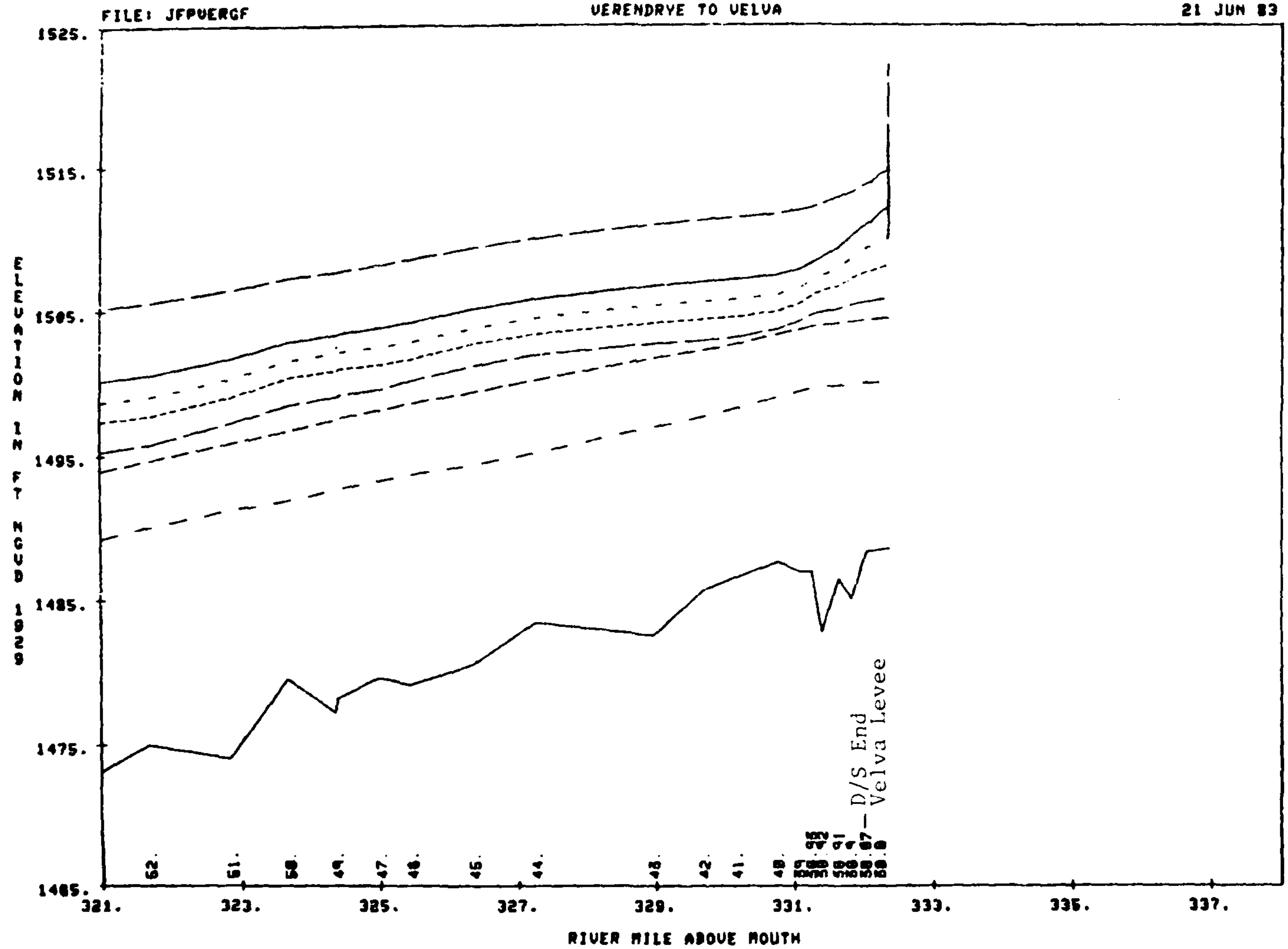


PLATE A-66

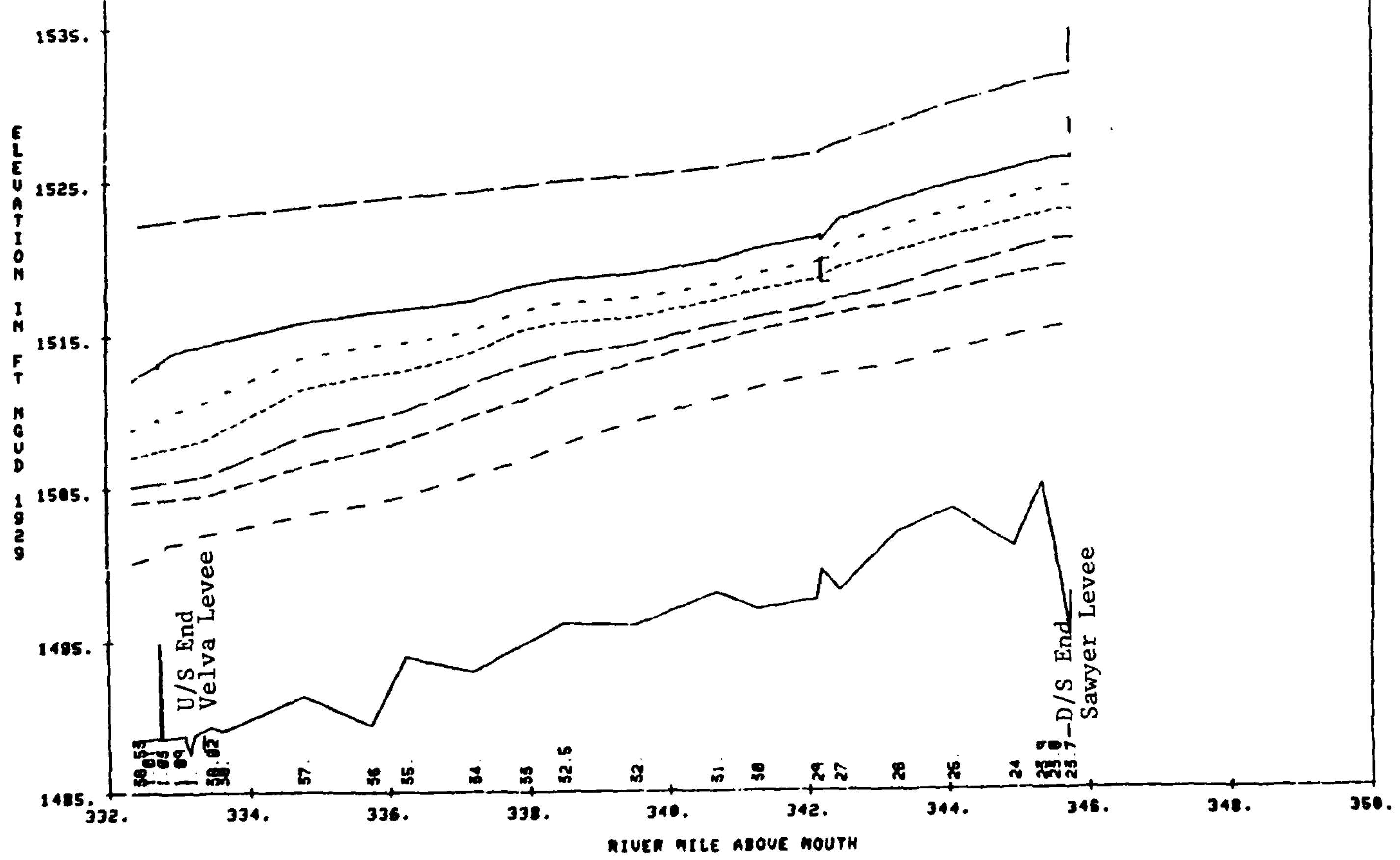

ELEVATION IN FT NGVD 1929
1535.
1525.
1515.
1505.
1495.
1485.
332.
334.
336.
338.
340.
342.
344.
346.
348.
350.
RIVER MILE ABOVE MOUTH
U/S End
Velva Levee
D/S End
Sawyer Levee
57
56
55
54
53
52.5
32
31
30
27
28
26
24
I BRIDGE

PLATE A-67

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL (9 of 13)
PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES
SAWYER TO LOGAN

21 JUN 83

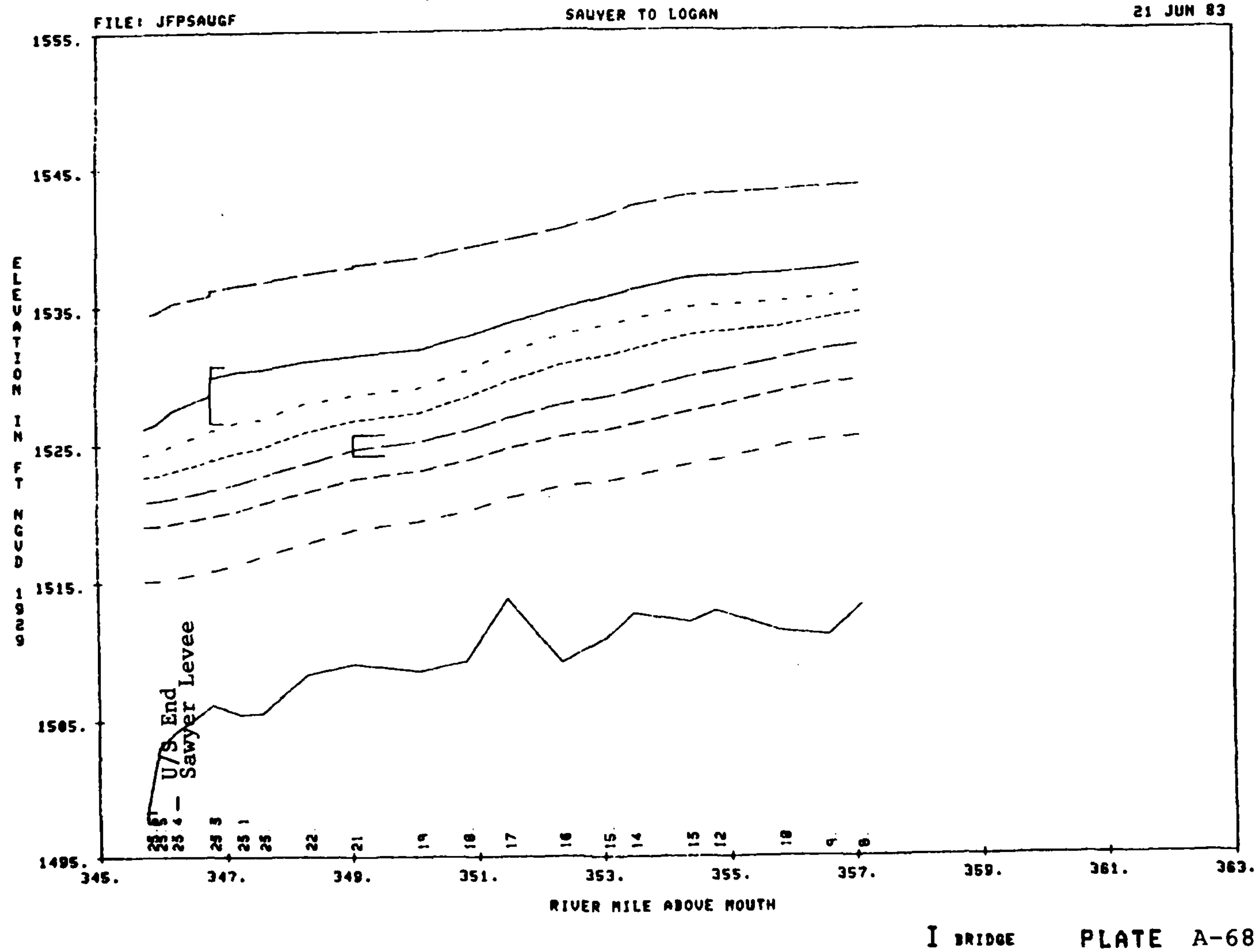


PLATE A-68

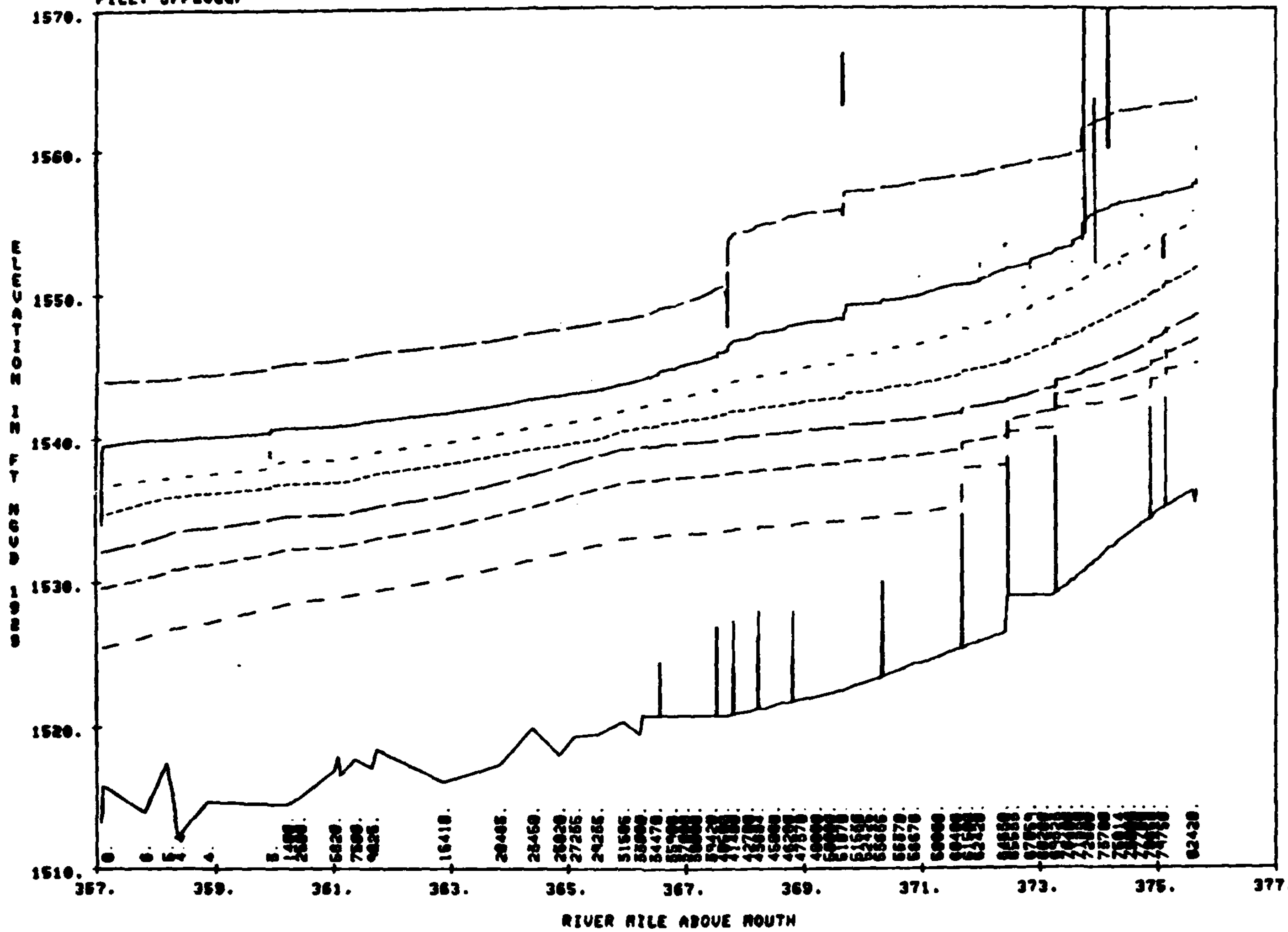
LAKE DARLING, SOURIS RIVER, NORTH DAKOTA   DM NO. 3, GENERAL

PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES

LOGAN TO MINOT

FILE: JFPLOGGF

22 JUN 83



I BRIDGE

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA   DM NO. 3, GENERAL

PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES

BURLINGTON TO LAKE DARLING DAM

FILE: JFPBURGF

22 JUN 83

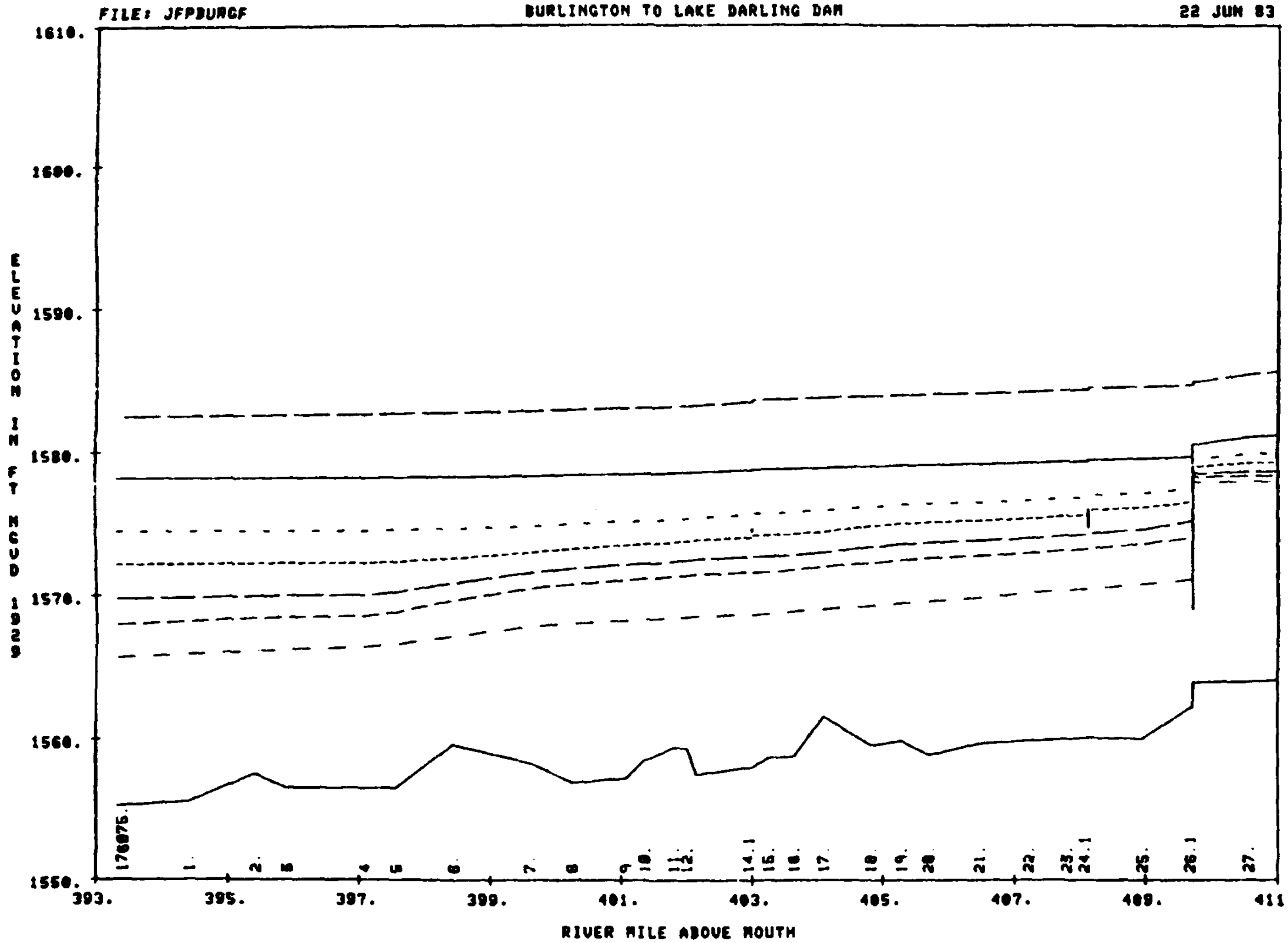


PLATE A-71

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL (13 of 13)
PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES
BURLINGTON TO LAKE DARLING DAM

FILE: JFPBURGF 22 JUN 83

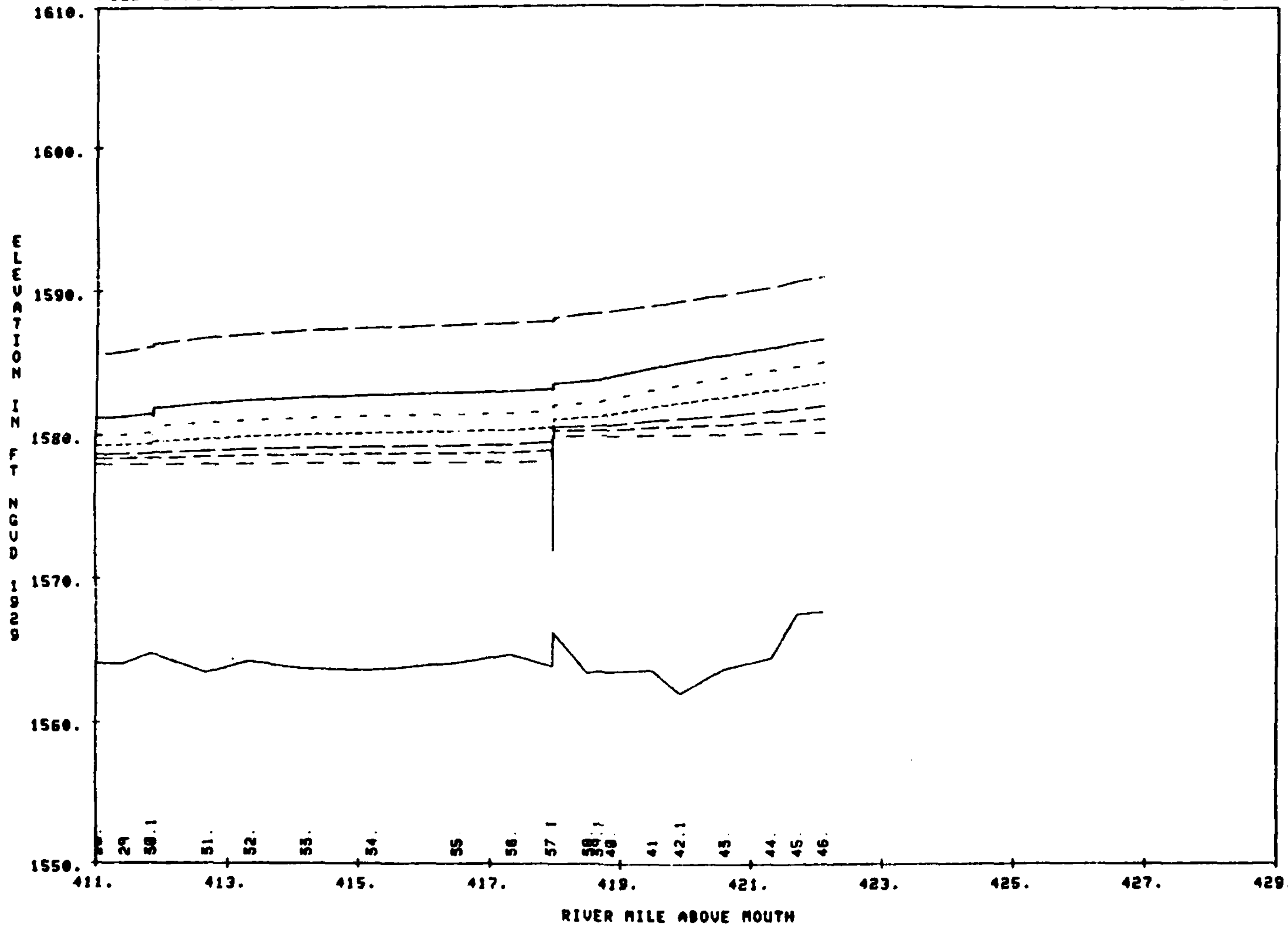
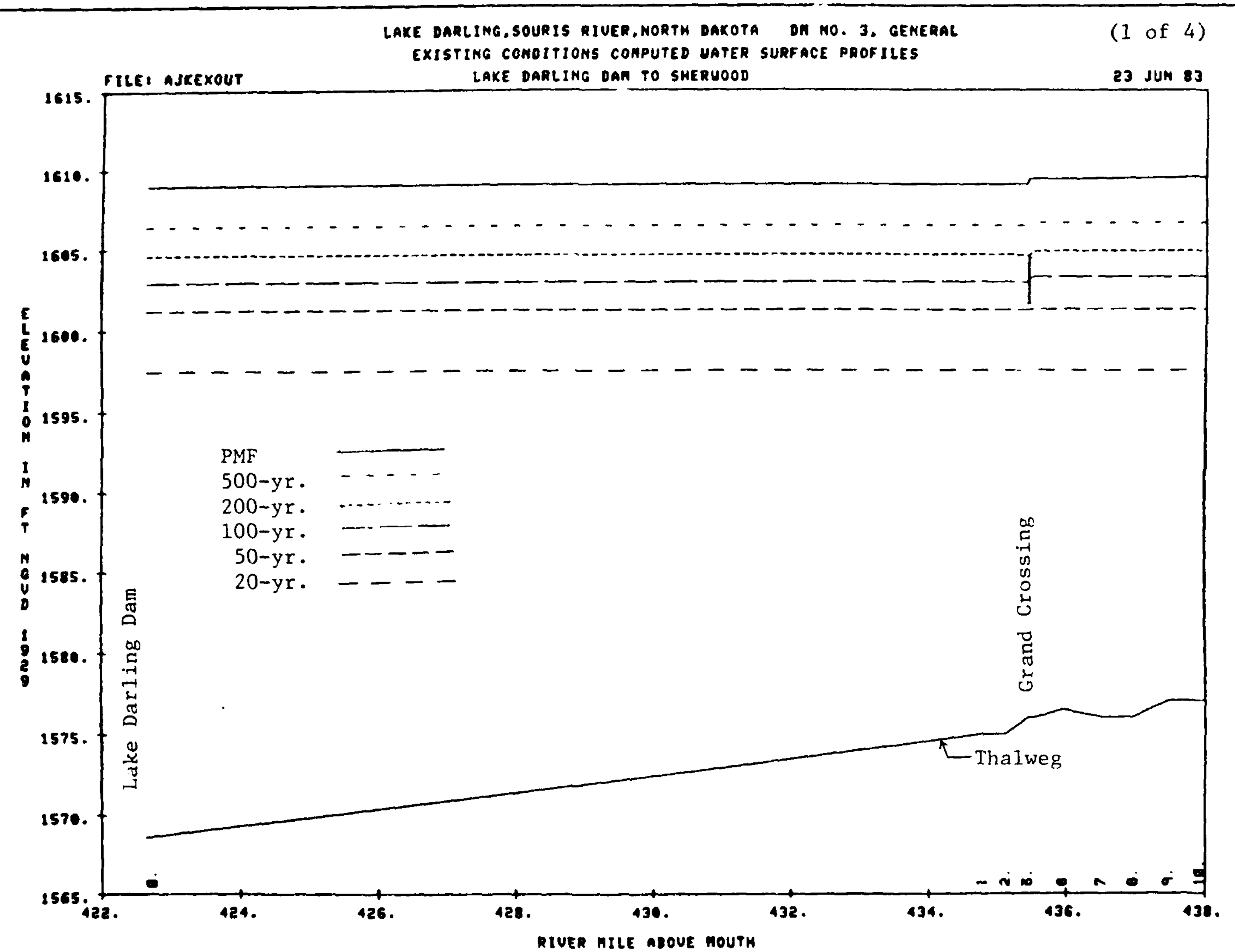


PLATE A-72



LAKE DARLING,SOURIS RIVER,NORTH DAKOTA DM NO. 3, GENERAL
(1 of 4)
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
LAKE DARLING DAM TO SHERWOOD
FILE: AJKEXOUT
23 JUN 83
ELEVATION IN FT NGVD 1929
1615.
1610.
1605.
1600.
1595.
1590.
1585.
1580.
1575.
1570.
1565.
PMF
500-yr.
200-yr.
100-yr.
50-yr.
20-yr.
Lake Darling Dam
Grand Crossing
Thalweg
422.
424.
426.
428.
430.
432.
434.
436.
438.
RIVER MILE ABOVE MOUTH
I BRIDGE

PLATE A-73

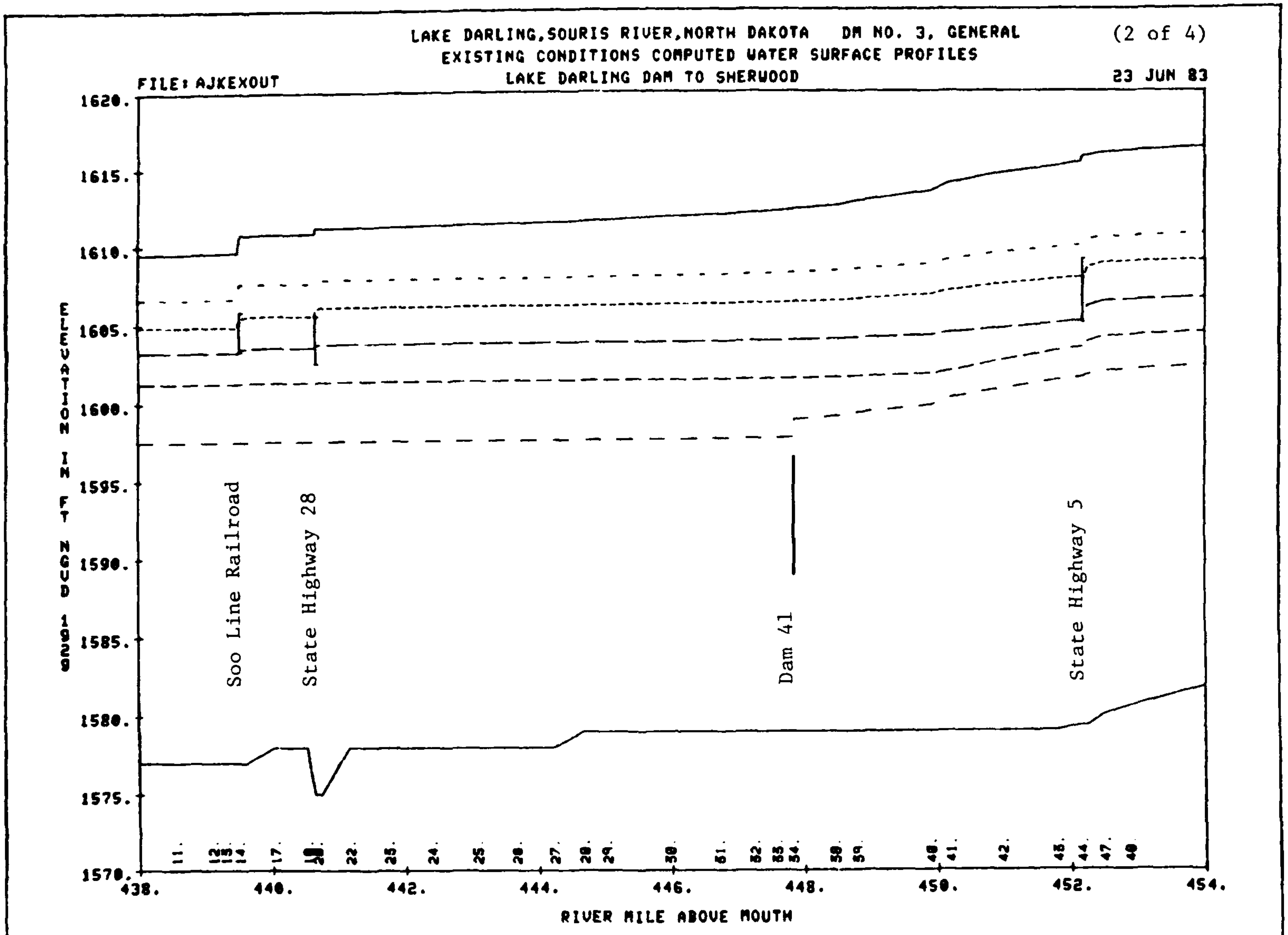

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL
(2 of 4)
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
LAKE DARLING DAM TO SHERWOOD
FILE: AJKEXOUT
23 JUN 83
ELEVATION IN FT NGVD 1929
RIVER MILE ABOVE MOUTH
Soo Line Railroad
State Highway 28
Dam 41
State Highway 5
I BRIDGE

PLATE A-74

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL (3 of 4)
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
LAKE DARLING DAM TO SHERWOOD
23 JUN 83

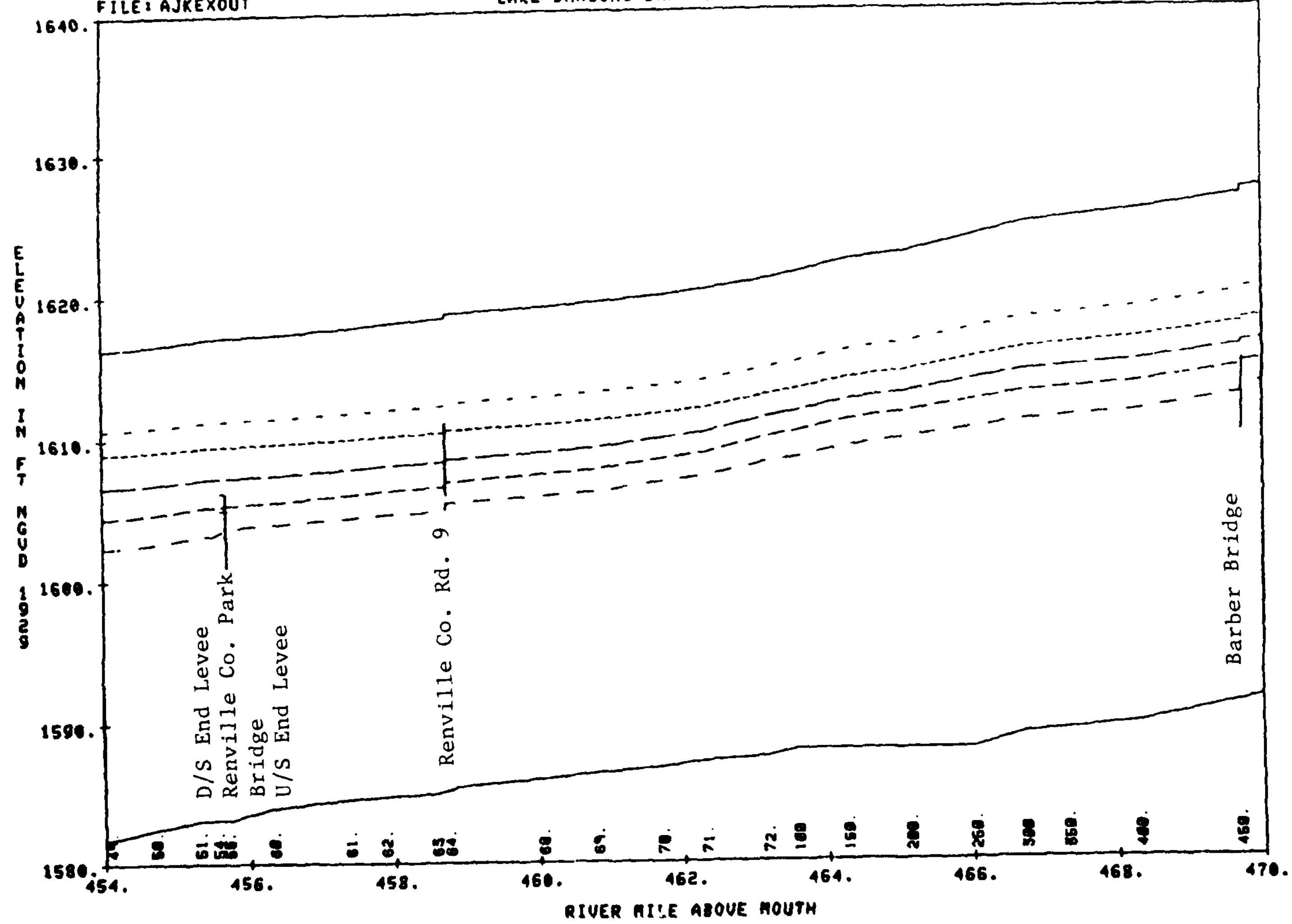


PLATE A-75

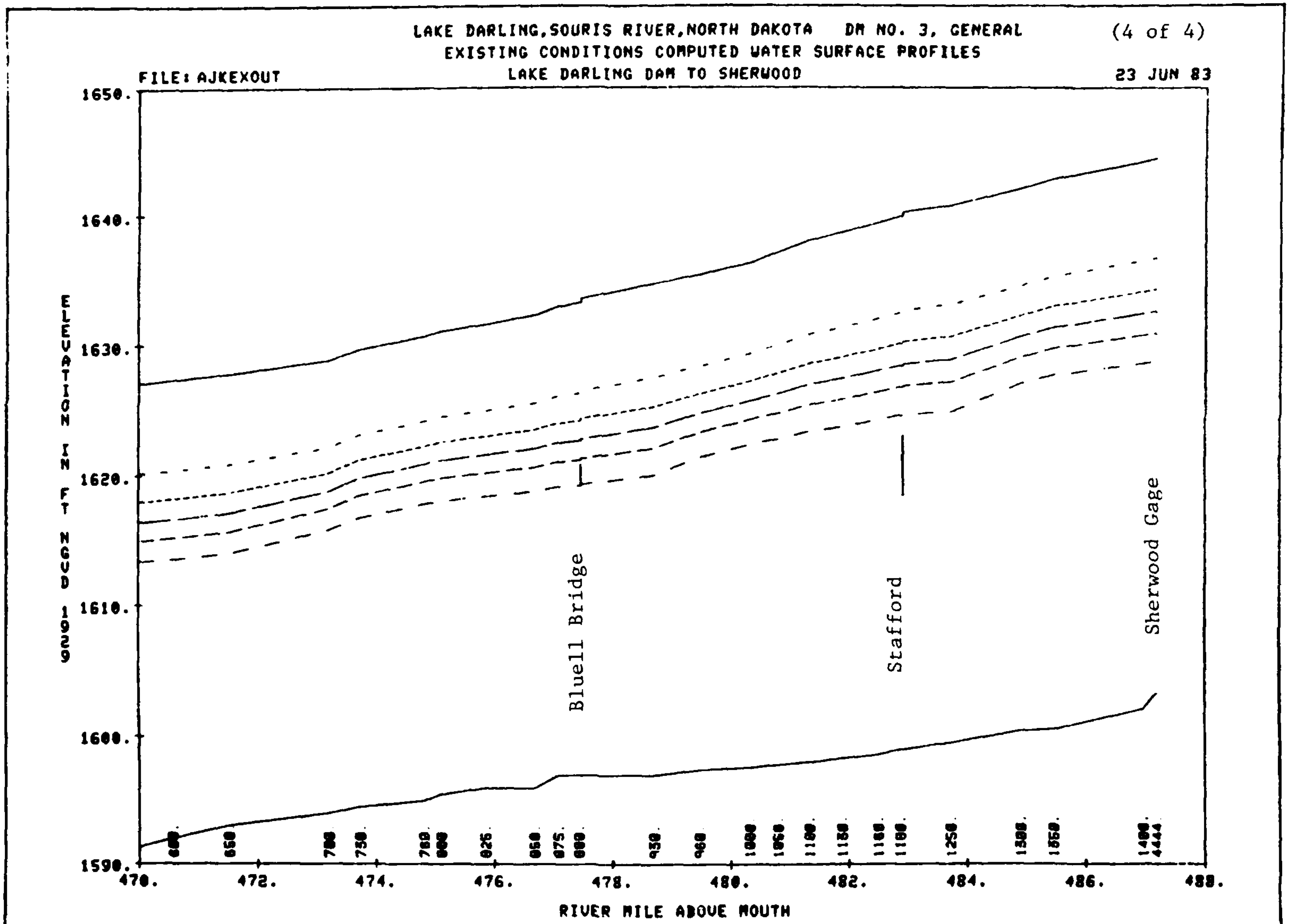

LAKE DARLING,SOURIS RIVER,NORTH DAKOTA DM NO. 3, GENERAL
(4 of 4)
EXISTING CONDITIONS COMPUTED WATER SURFACE PROFILES
LAKE DARLING DAM TO SHERWOOD
FILE: AJKEXOUT
23 JUN 83
ELEVATION IN FT NGVD 1929
1650.
1640.
1630.
1620.
1610.
1600.
1590.
470.
472.
474.
476.
478.
480.
482.
484.
486.
488.
RIVER MILE ABOVE MOUTH
Bluell Bridge
Stafford
Sherwood Gage
600
650
700
730
760
800
825
850
875
880
950
960
1000
1050
1100
1130
1160
1180
1250
1300
1350
1400
4444
I BRIDGE

PLATE A-76

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL (1 of 4)
PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES
LAKE DARLING DAM TO SHERWOOD

FILE: AJKPPOUT 22 JUN 83

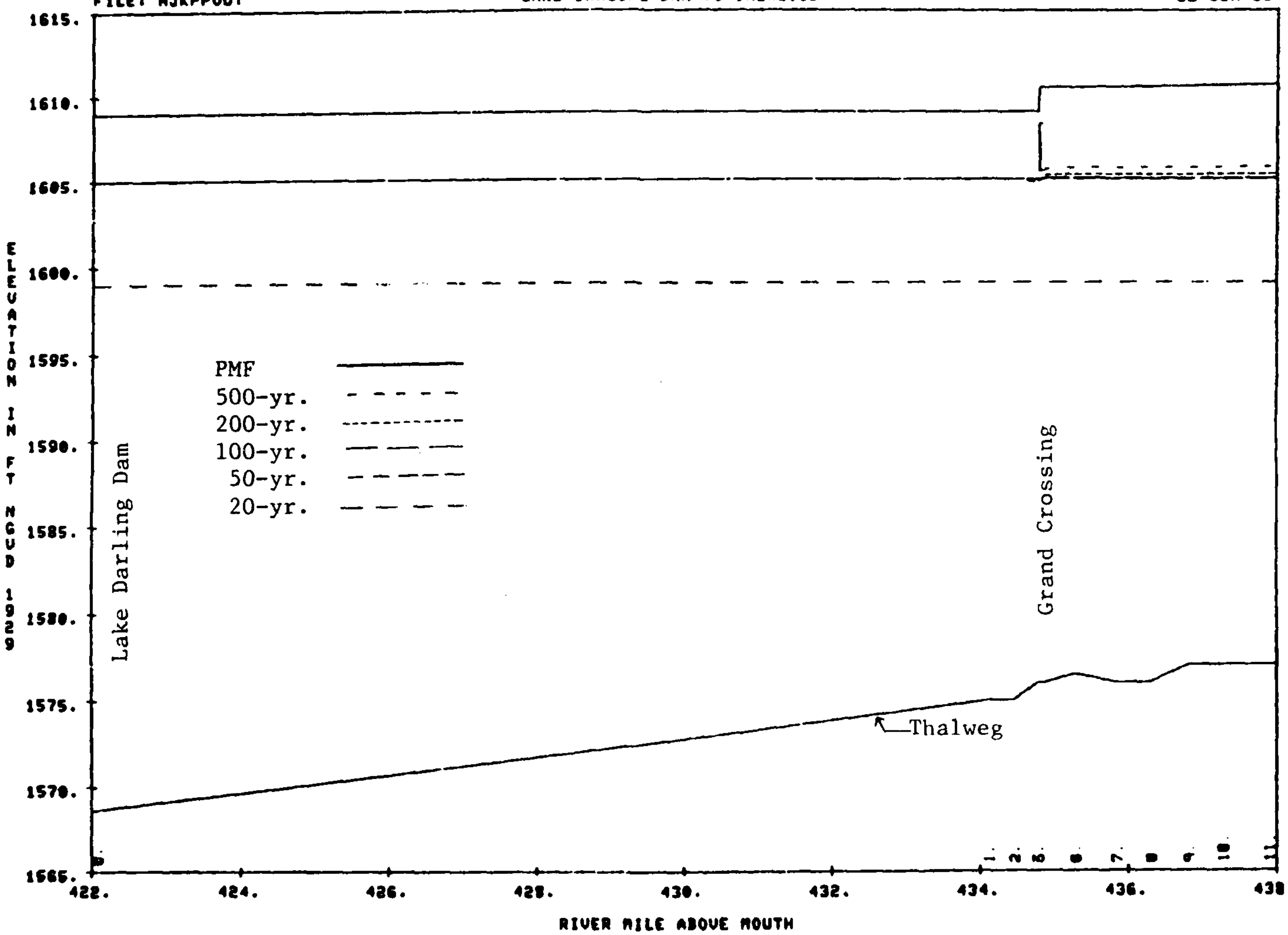


PLATE A-77

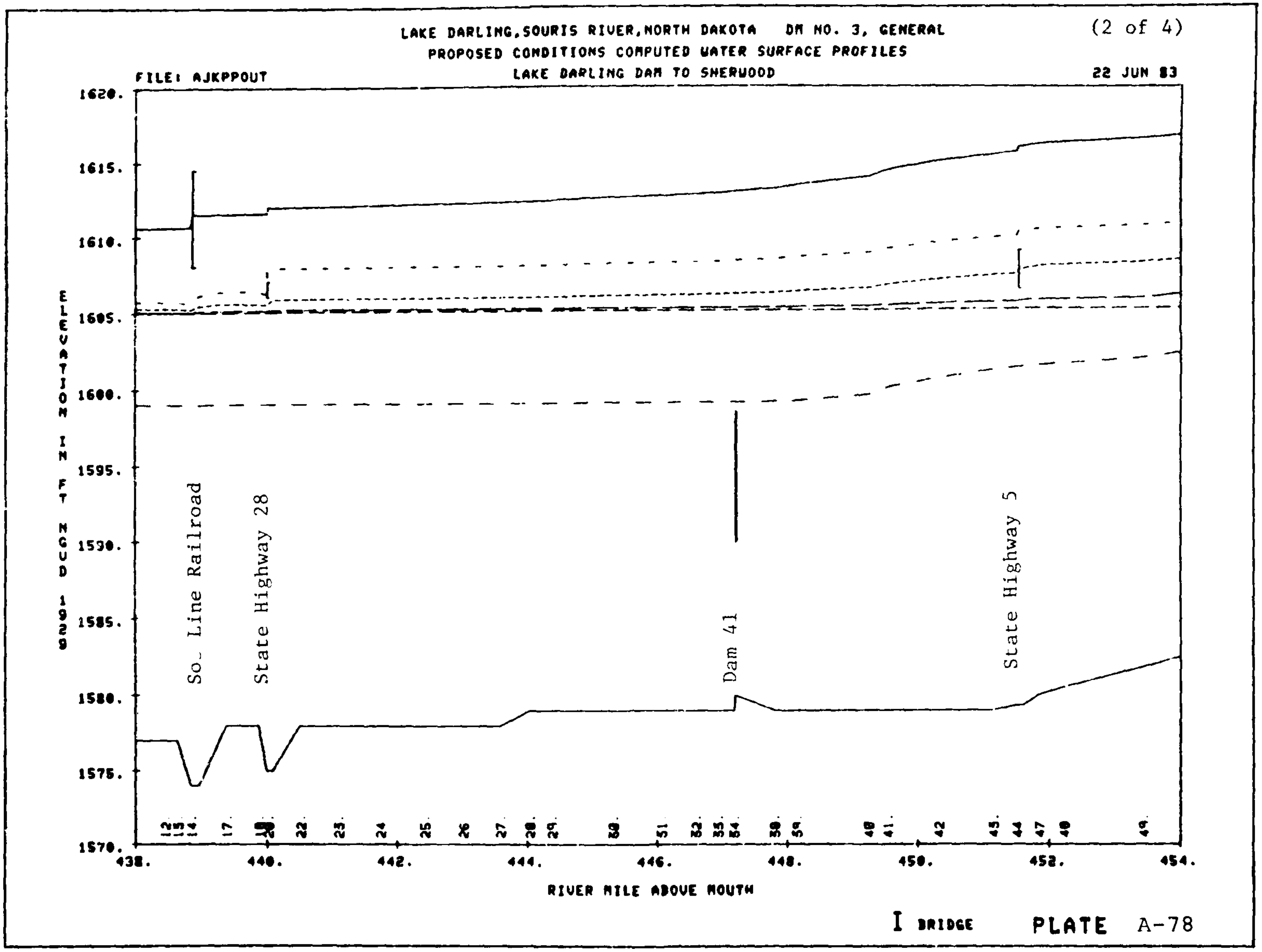
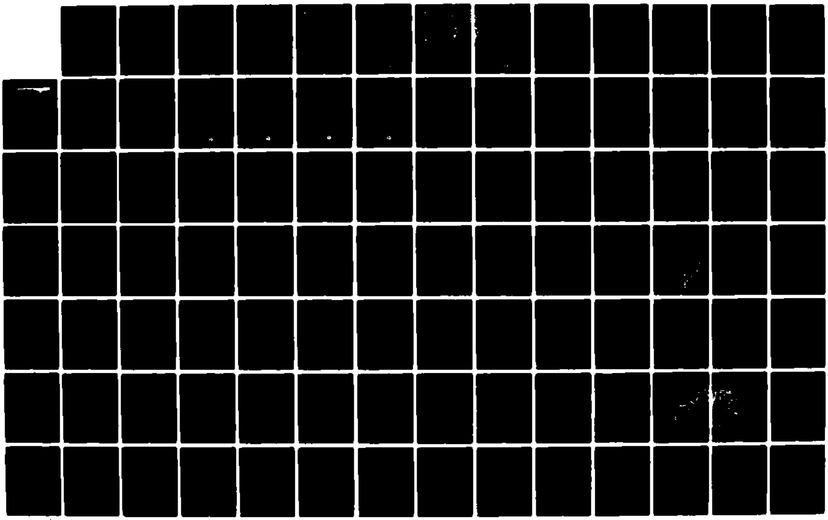
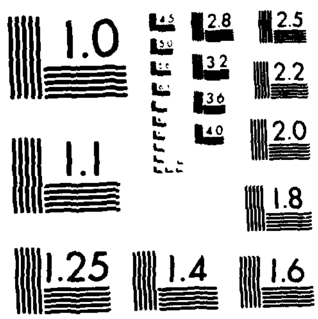

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL
PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES
LAKE DARLING DAM TO SHERWOOD
(2 of 4)
FILE: AJKPPOUT
22 JUN 83
ELEVATION IN FT NGVD 1929
RIVER MILE ABOVE MOUTH
So. Line Railroad
State Highway 28
Dam 41
State Highway 5
I BRIDGE

PLATE A-78

AD-A136 228 LAKE DARLING FLOOD CONTROL PROJECT SOURIS RIVER NORTH DAKOTA GENERAL PROJECT DESIGN(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT JUN 83 6/7

UNCLASSIFIED F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

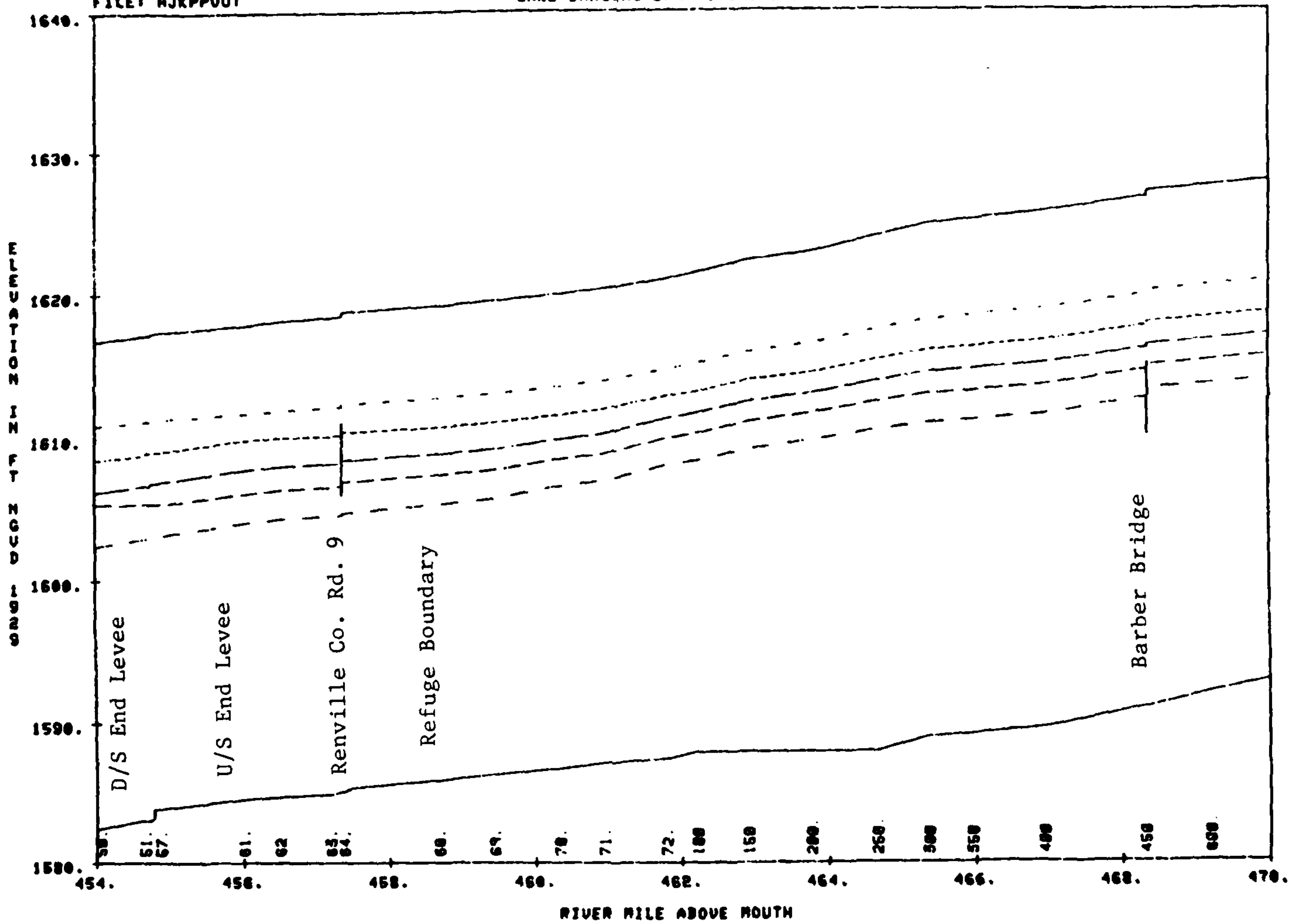
LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL

PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES

LAKE DARLING DAM TO SHERWOOD

FILE: AJKPPOUT

22 JUN 83



I BRIDGE

PLATE A-79

(4 of 4)

LAKE DARLING, SOURIS RIVER, NORTH DAKOTA DM NO. 3, GENERAL
PROPOSED CONDITIONS COMPUTED WATER SURFACE PROFILES
LAKE DARLING DAM TO SHERWOOD

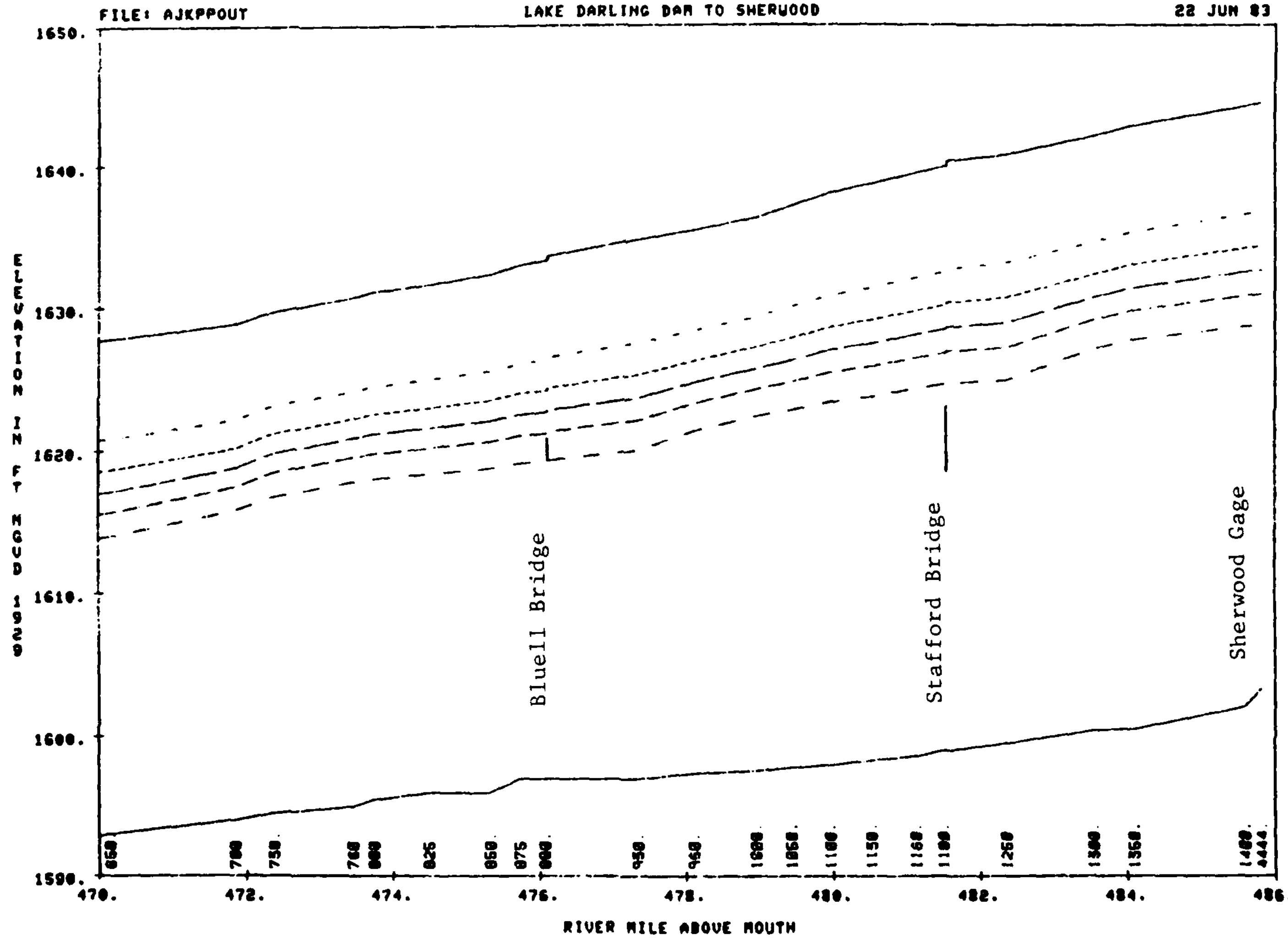
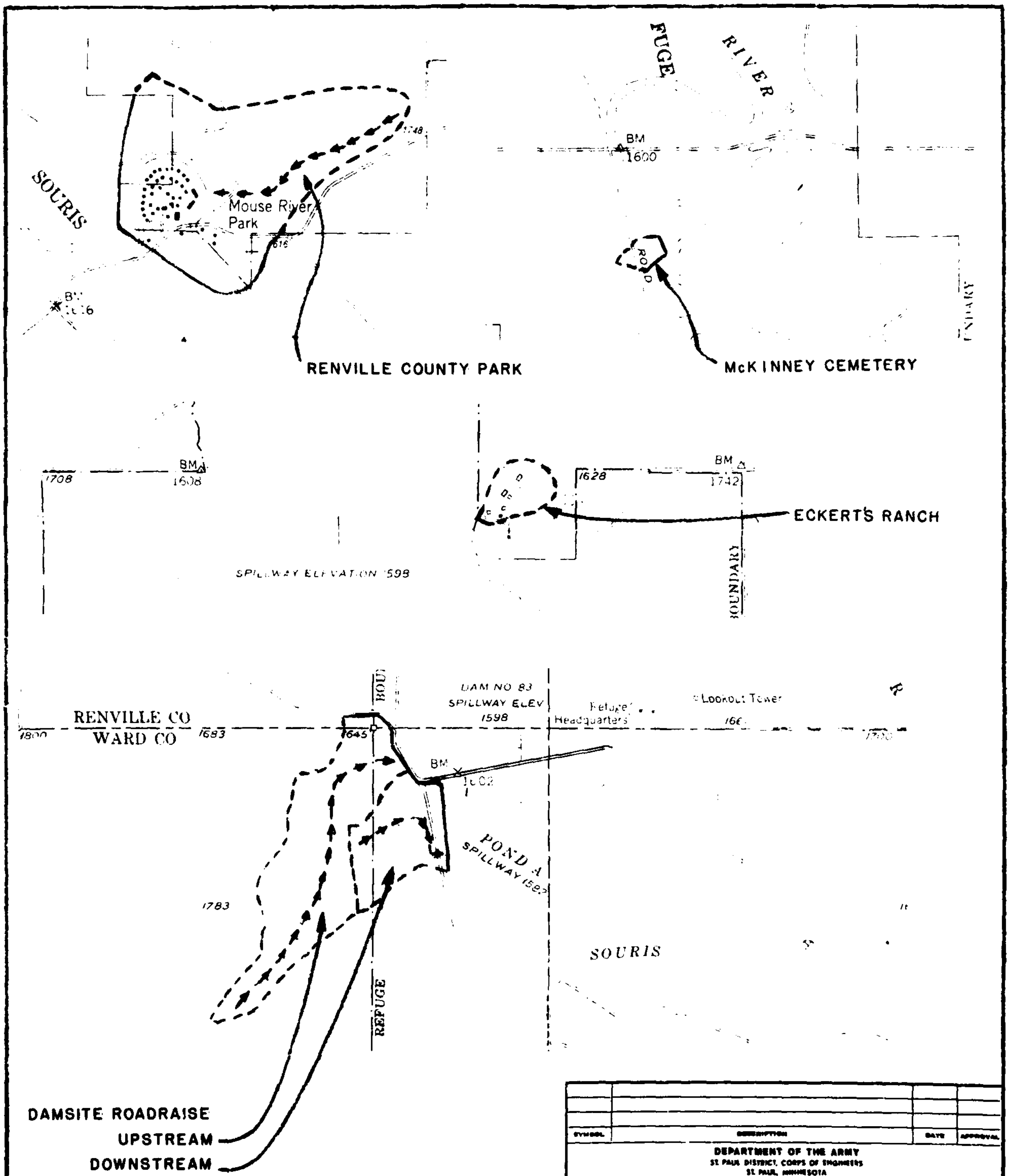


PLATE A-80



SYMBOL	DESCRIPTION	DATE	APPROVAL

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

DRAINAGE AREA BOUNDARIES

ST. PAUL, MN. DISTRICT

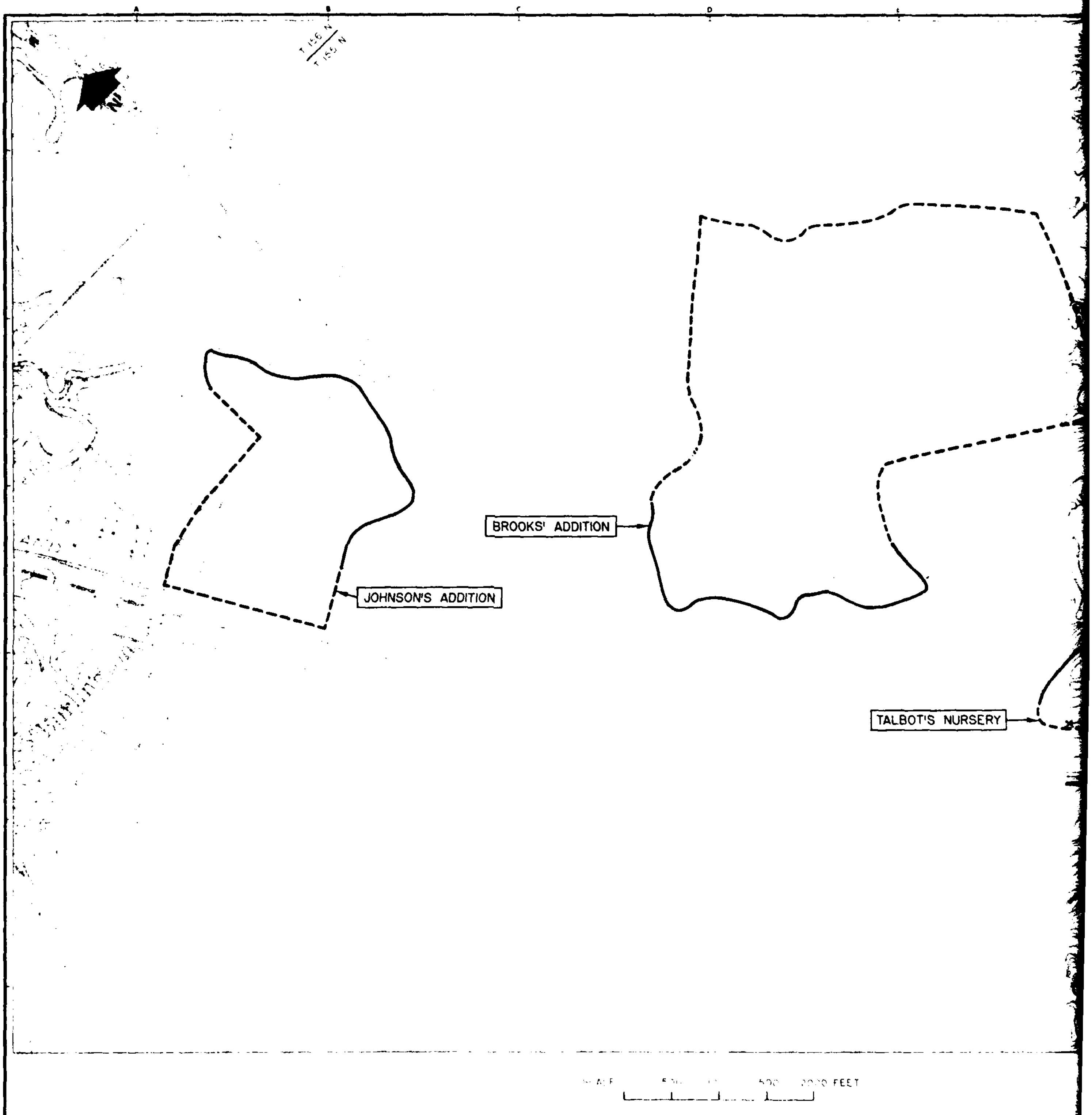
DESIGNED BY: W.J.H.
DRAWN BY: J.M.J.
CHECKED BY: W.J.H.
SUBMITTED BY:
APPROVED:

DATE: JUNE 1983

DRAWING NUMBER RI-R-5/

SHEET OF

PLATE A-81



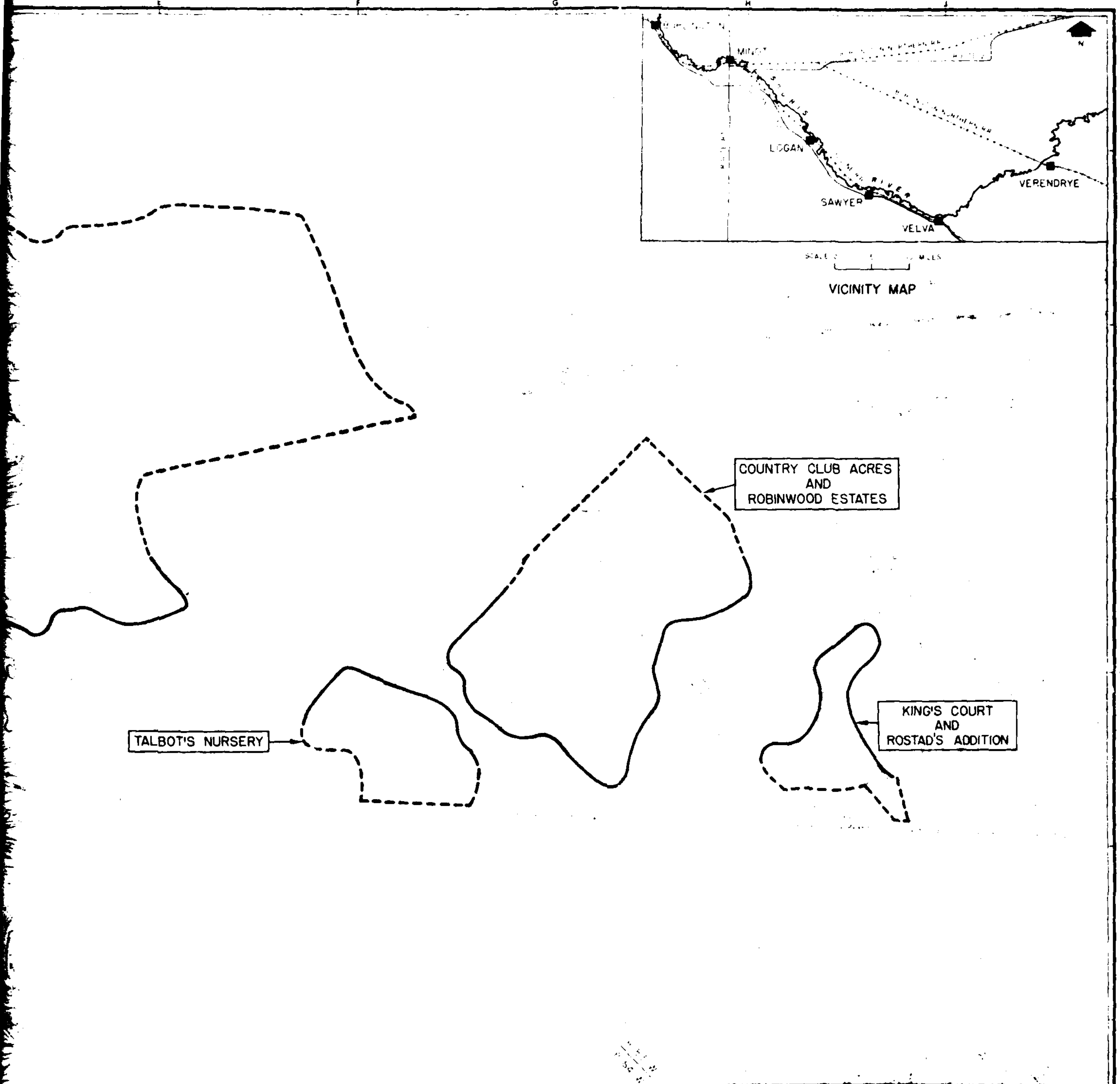
LEGEND

DRAINAGE AREA BOUNDARY

LEVEE ALIGNMENT

NOTES:

1. BASE MAP IS FROM USGS 7.5 MINUTE TOPOGRAPHIC MAPS: BURLINGTON, BURL
MINOT NW AND MINOT



1500 2000 FEET

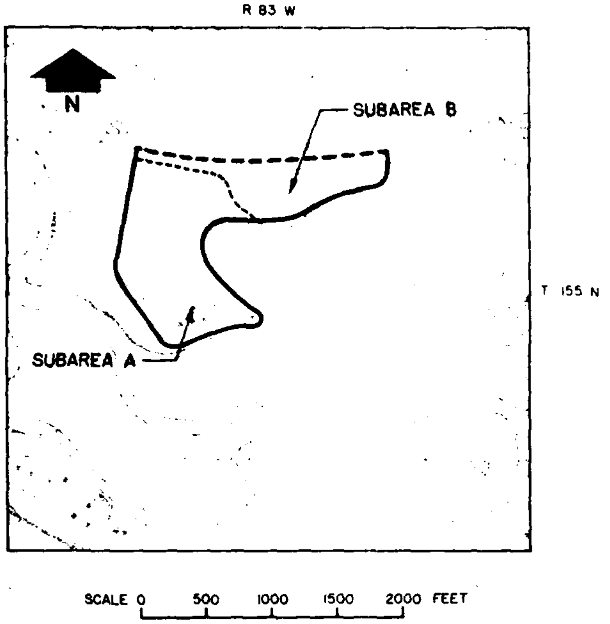
NOTES:

1. BASE MAP IS FROM USGS 7.5 MINUTE TOPOGRAPHIC MAPS: BURLINGTON, BURLINGTON SE, MINOT NW AND MINOT

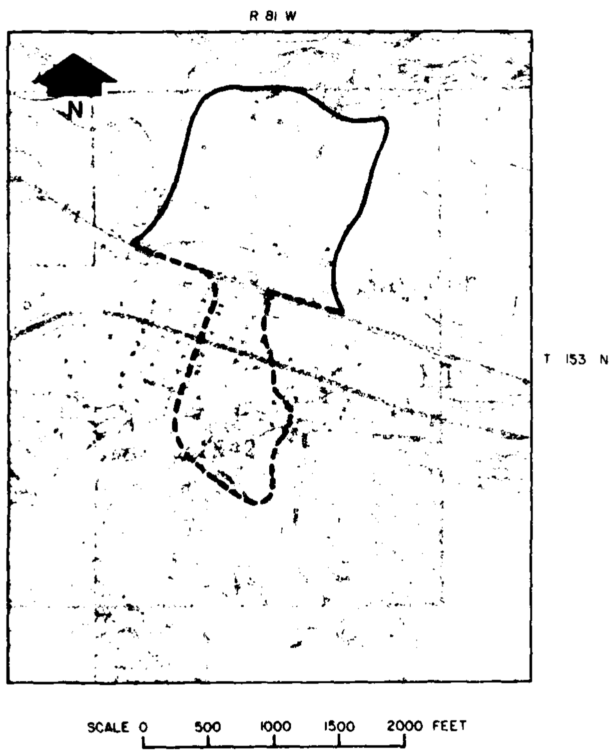
DEPARTMENT OF THE ARMY	
J.F. L.M.S.	FLOOD CONTROL - LAKE DARLING
J.J.	SOURIS RIVER, NORTH DAKOTA
J.F. L.M.S.	DRAINAGE AREA BOUNDARIES
	DATE: JUNE 1983
	RI-R-5/

PLATE A-82

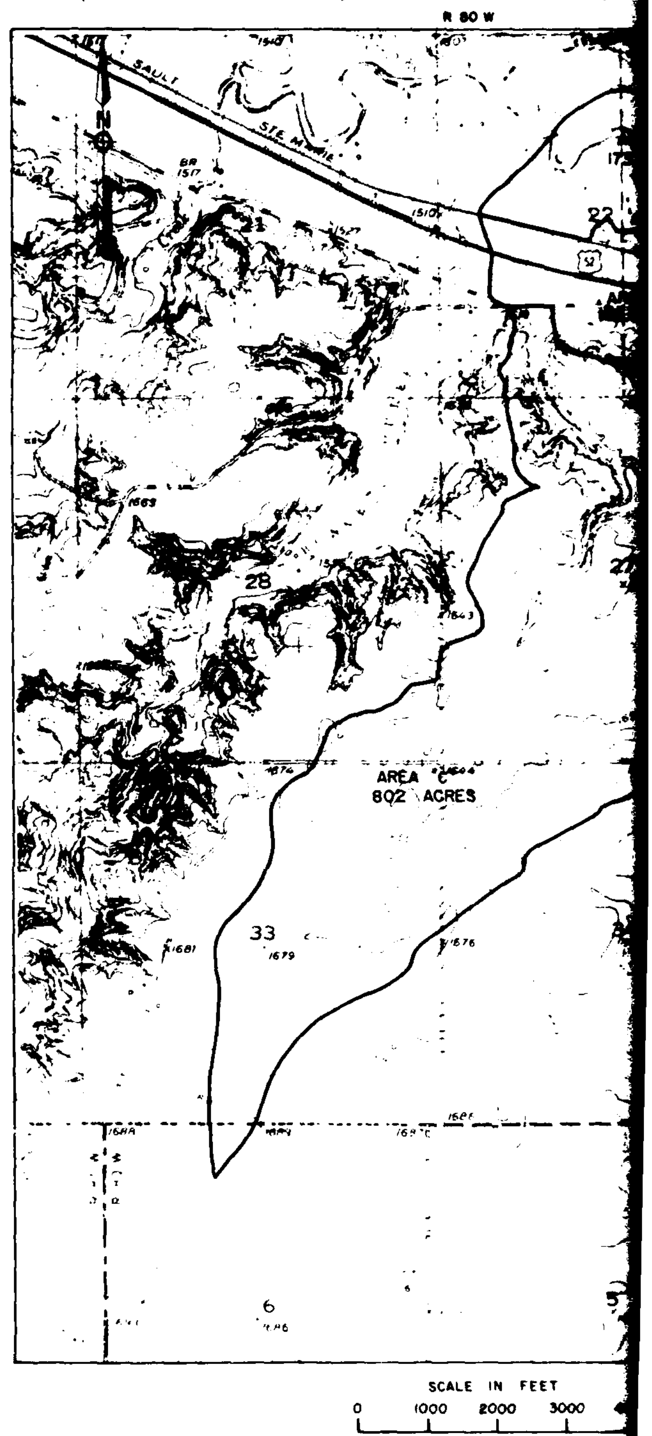
2



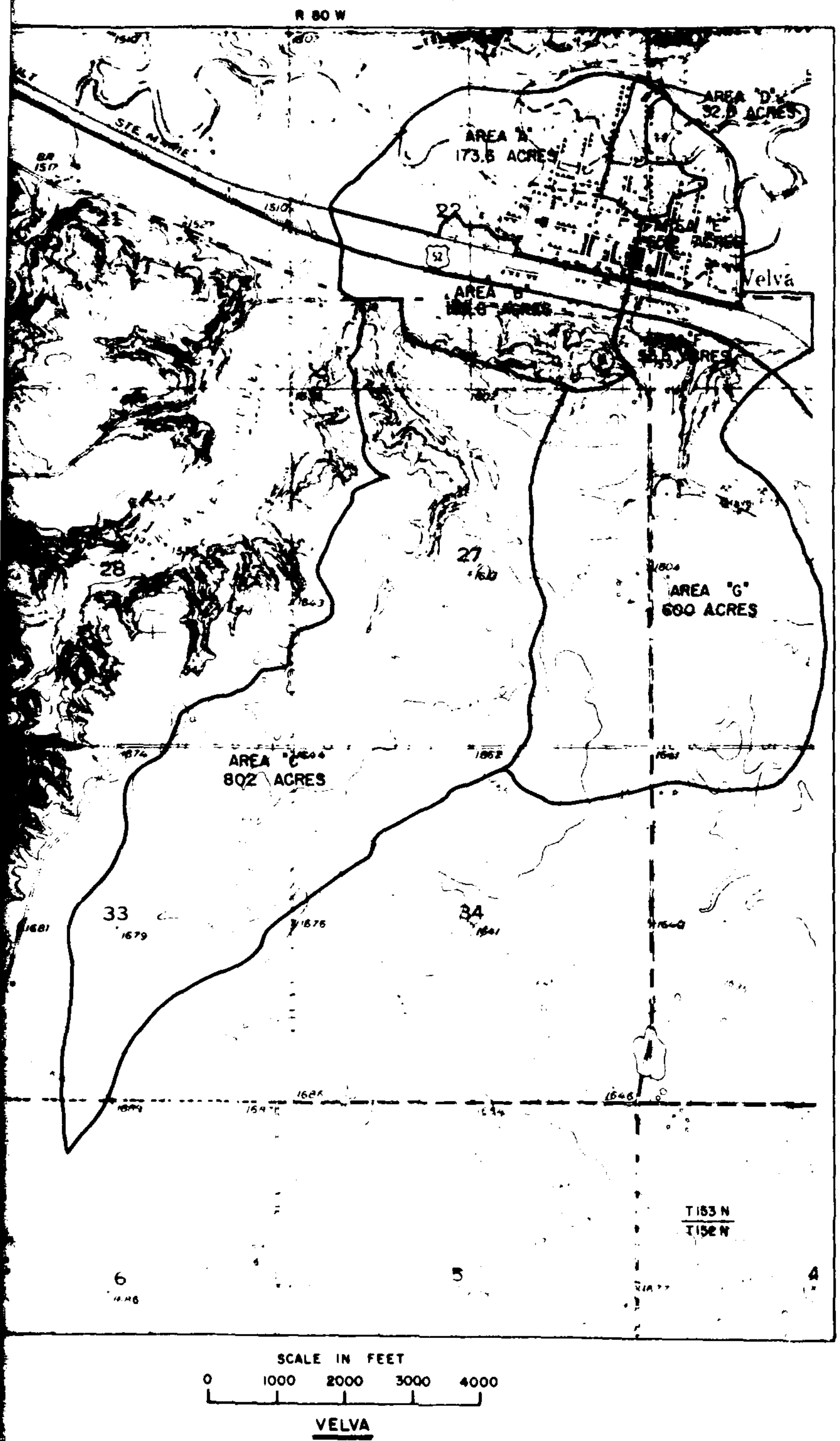
TIERRECITO VALLEJO



SAWYER



VELVA



LEGEND

- DRAINAGE AREA BOUNDARY
- SUB DRAINAGE AREA BOUNDARY
- LEVEE ALIGNMENT

NOTES:

1. BASE MAPS ARE FROM USGS 7.5 MINUTE TOPOGRAPHIC MAPS: MINOT, VELVA, AND SAWYER

DEPARTMENT OF THE ARMY

DESIGN MEMORANDUM NO 3 GENERAL

W. J. M.

J. M. J.

W. J. M.

SUBMITTED BY:

APPROVED:

FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

VELVA IMPROVEMENTS

DRAINAGE AREA BOUNDARIES

JUNE 1983

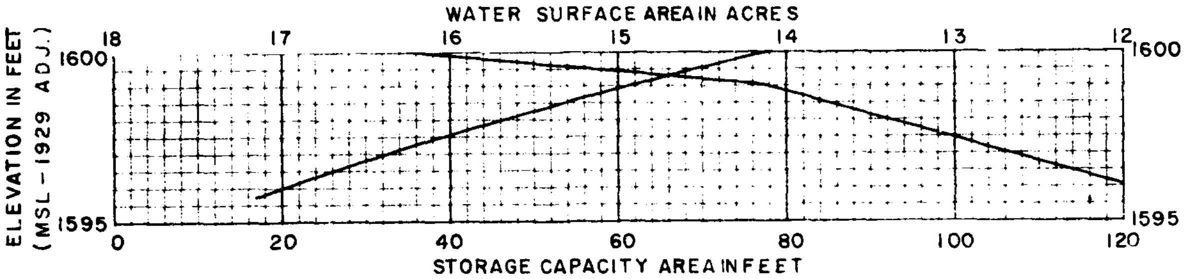
AS SHOWN

RI-R-5/

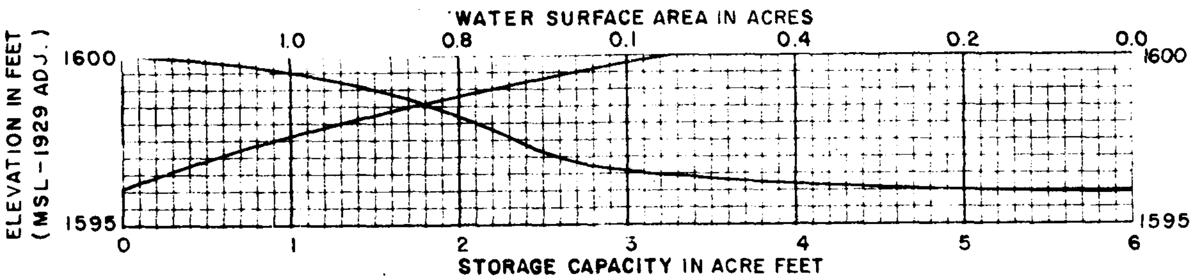
SAFETY PAYS

PLATE A- 83

1 2



RENVILLE COUNTY PARK



EKERT'S RANCH

DEPARTMENT OF THE ARMY

W.J.M

J.M.J.

W.J.M.

APPROVED

DESIGN MEMORANDUM NO. 3 GENERAL

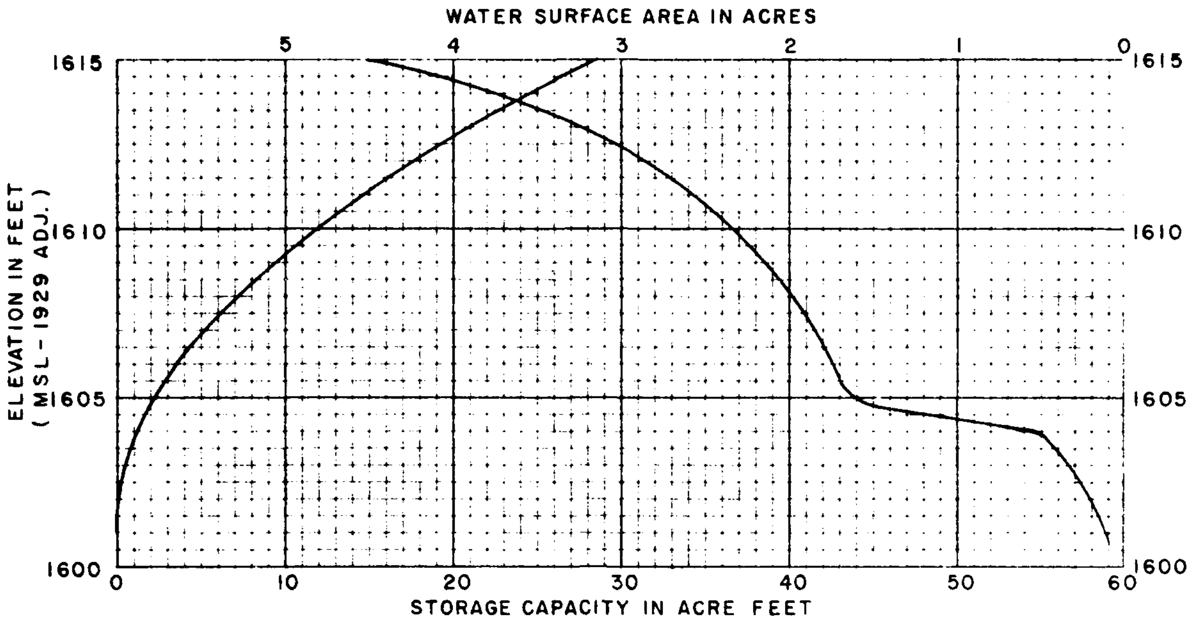
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

ELEVATION-AREA-CAPACITY CURVES

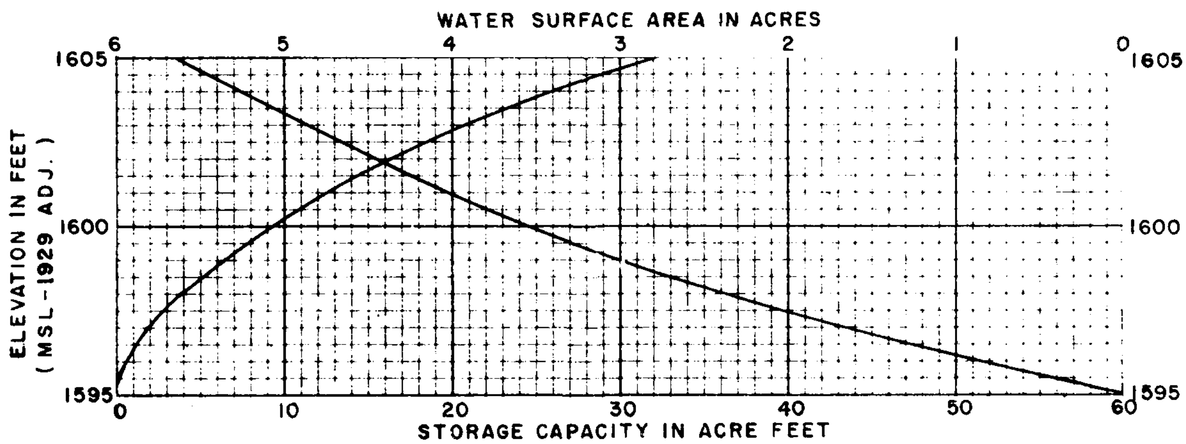
ST. PAUL, MN. DISTRICT

DATE: JUNE 1983

DRAWING NUMBER
RI-R-5/



DAMSITE-UPSTREAM



DAMSITE-DOWNSTREAM

DEPARTMENT OF THE ARMY

ST. PAUL DISTRICT, CORPS OF ENGINEERS

ST. PAUL, MINNESOTA

W.J.M

J.M.J.

W.J.M.

SUBMITTED BY:

APPROVED:

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING

SOURIS RIVER, NORTH DAKOTA

ELEVATION - AREA - CAPACITY CURVES

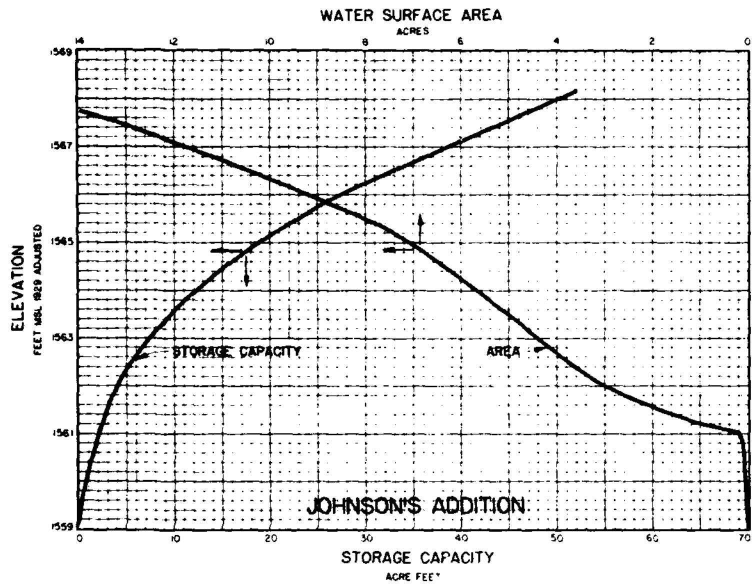
ST. PAUL, MN. DISTRICT

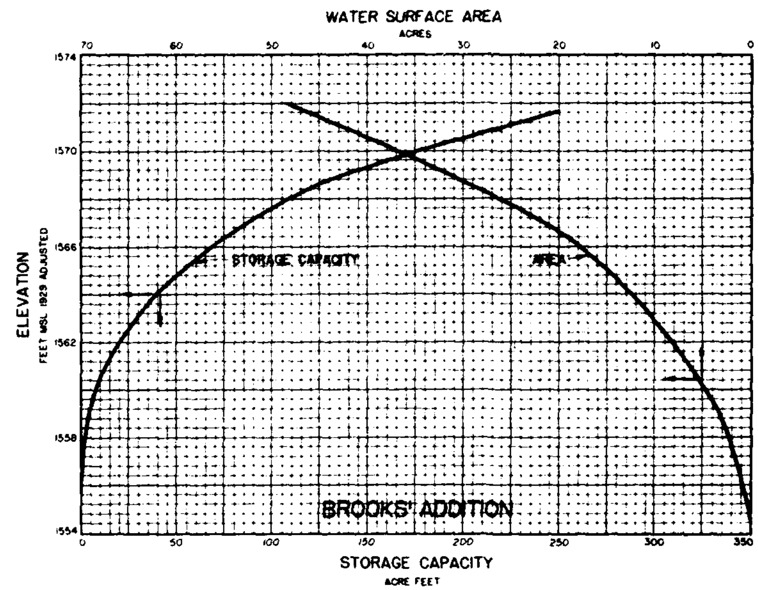
DATE: JUNE 1983

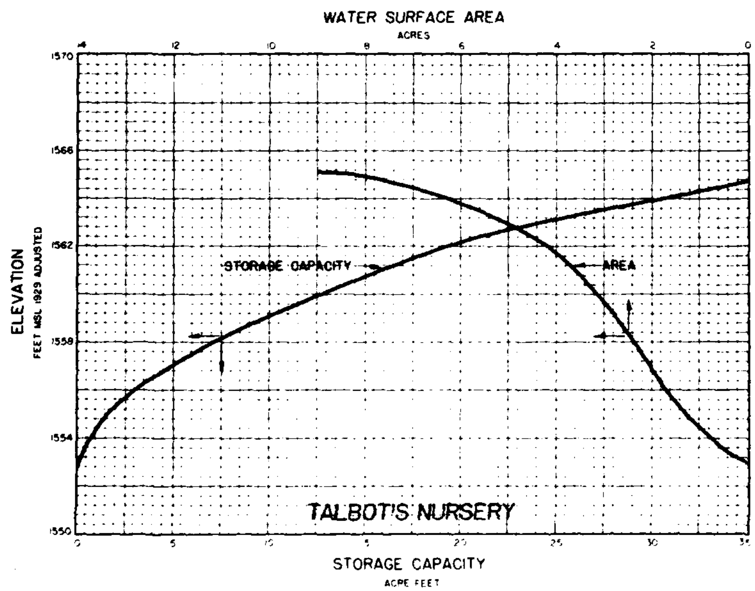
DRAWING NUMBER

RI-R-5/

SHEET OF





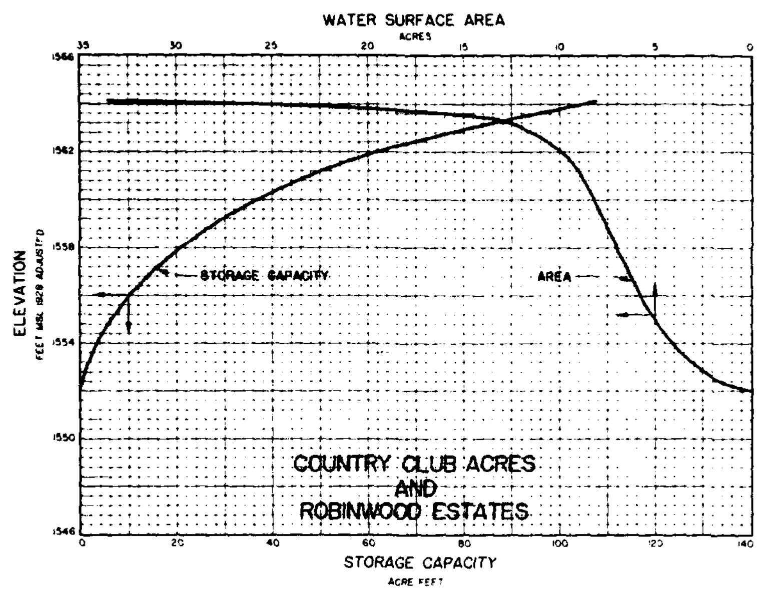


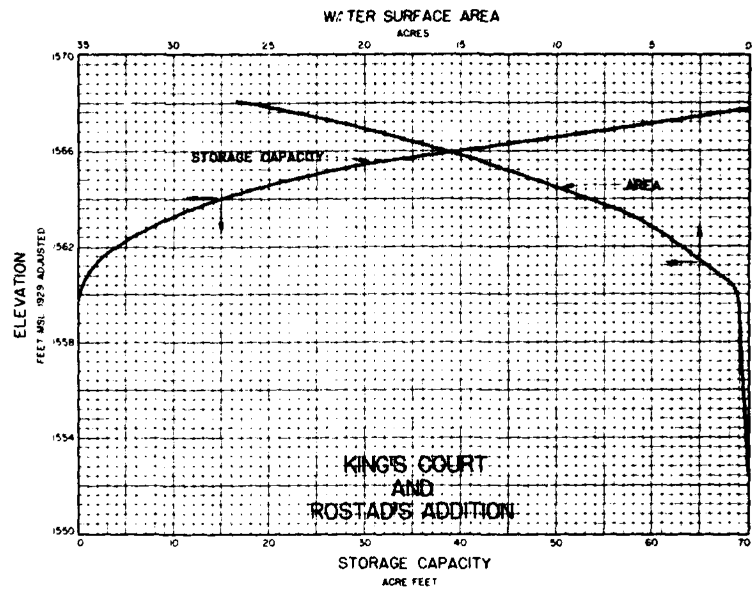
SAFETY PAYS

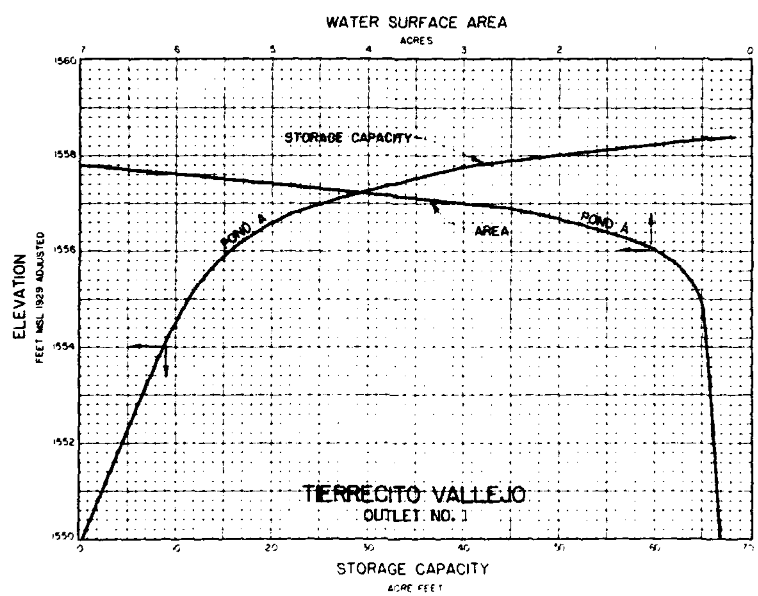
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

ELEVATION-AREA-CAPACITY CURVES

PLATE NO. A-P6



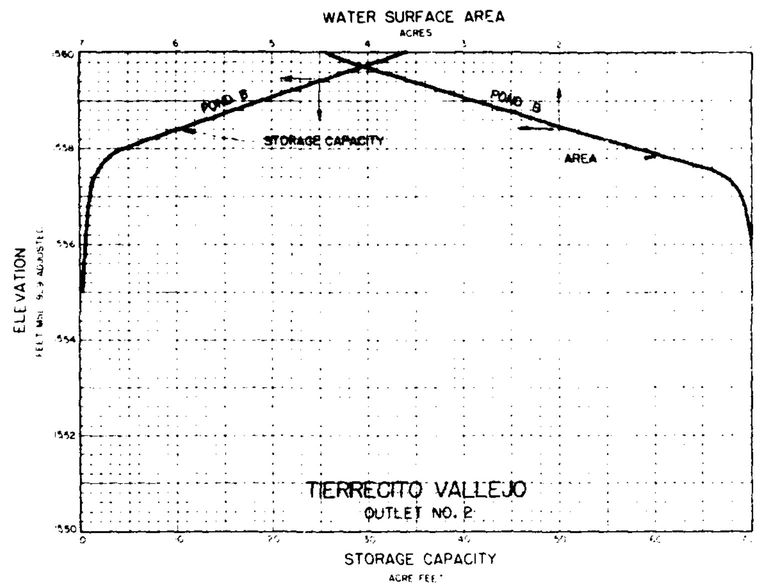


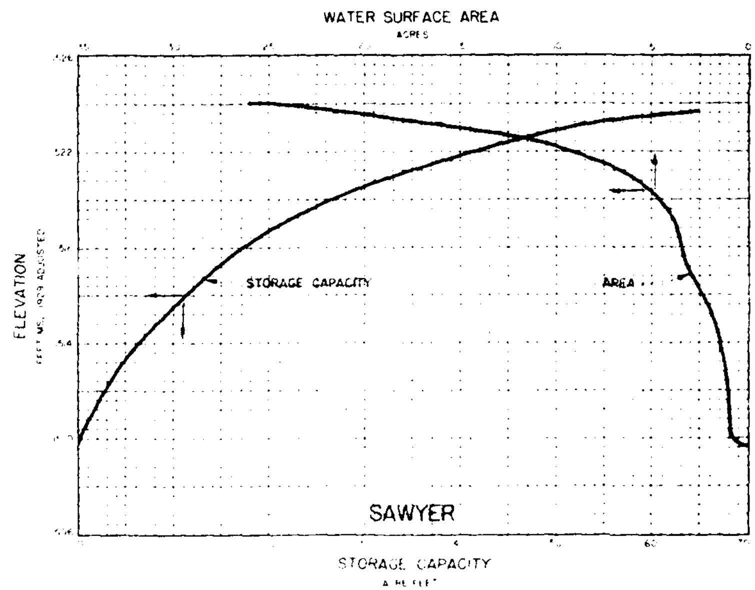


DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

ELEVATION-AREA-CAPACITY CURVES

PLATE NO. A-87

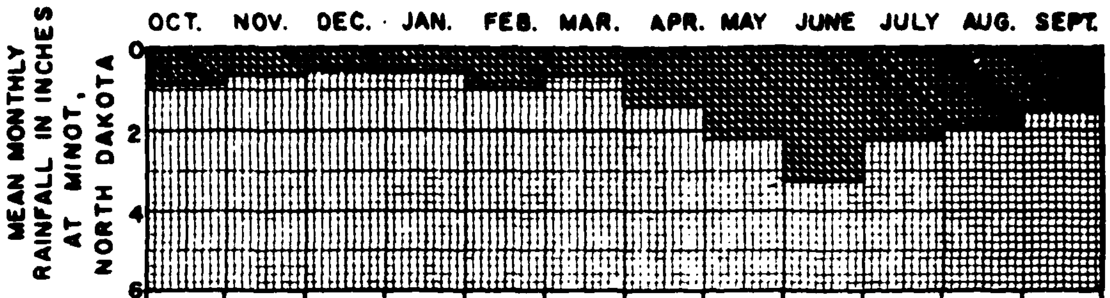




DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

ELEVATION-AREA-CAPACITY CURVES

PLATE NO.



	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.
(1) AVE. MONTH	.86	.66	.51	.53	.97	.65	1.40	2.21	3.25	2.23	1.90	1.48
(2) MAX. MONTH	3 30	3.33	1.82	2.40	2.12	2.18	5.71	6.15	10.63	7.20	4.89	6.11
YEAR	1971	1922	1967	1916	1922	1971	1970	1963	1944	1935	1964	1971
(3) MAX. 24—HRS.	1.26	2.20	1.20	1.00	1.20	1.07	2.40	3.00	3.70	3.89	2.40	3.40
YEAR	1924	1922	1918	1916	1922	1950	1903	1903	1914	1971	1899	1903

Note:

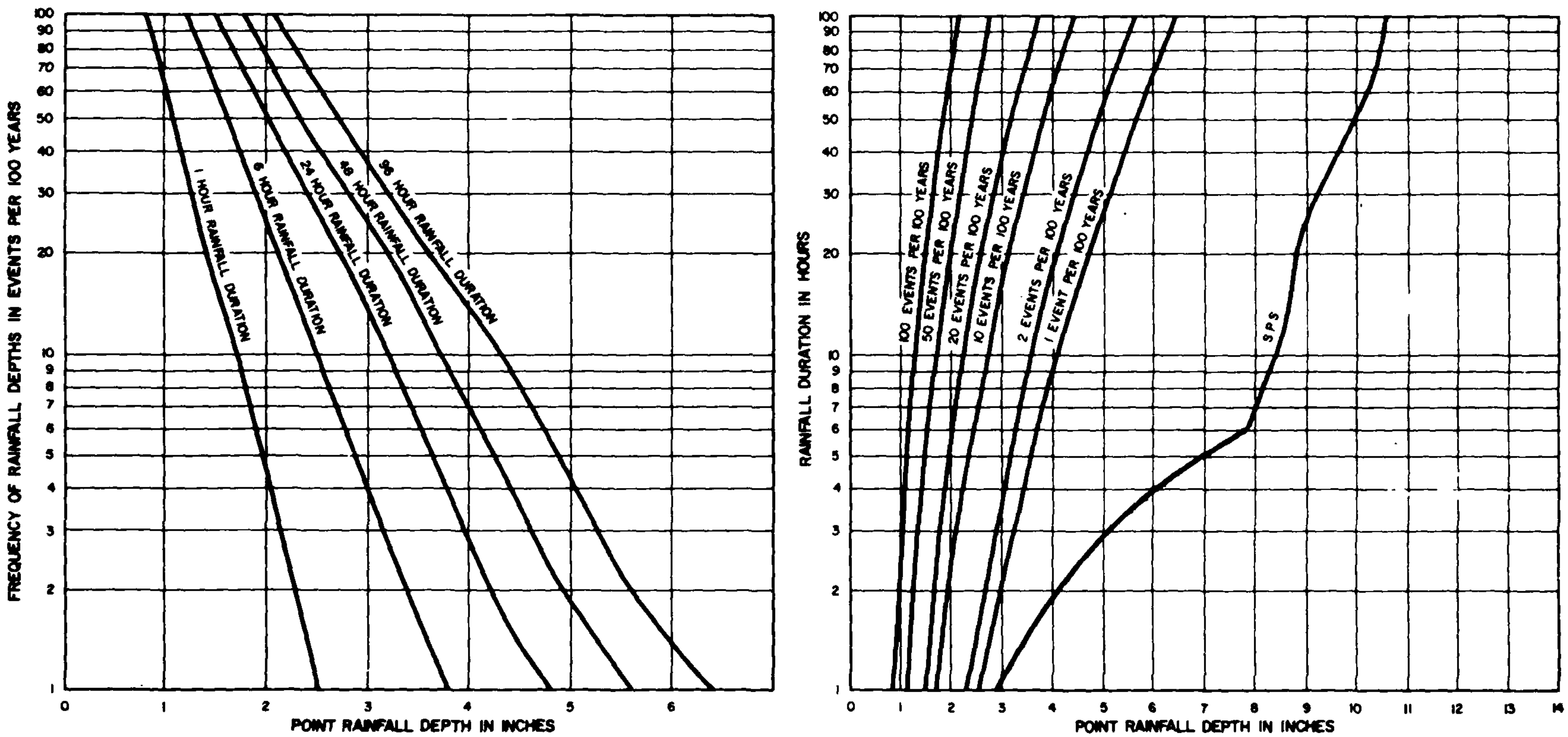
1. Period of record, 1906-1972.

Source:

Flood control, Souris River at
Minot, North Dakota, Design Memorandum No. 2,
Interior Drainage.

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

MONTHLY RAINFALL



DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
POINT RAINFALL DEPTH CURVES

MAXIMUM RAINFALL DURATION IN HOURS	RAINFALL IN INCHES OF DEPTH CORRESPONDING TO VARIOUS AVERAGE FREQUENCIES AND DURATION IN HOURS						
	AVERAGE EXCEEDENCE INTERVAL IN PERCENT						
	100	50	20	10	2	1	SPS
	MAXIMUM ACCUMULATION OF RAINFALL FOR DURATION SHOWN IN FAR LEFT COLUMN						
1	0.8	1.1	1.4	1.7	2.3	2.5	2.9
2	0.9	1.2	1.7	1.9	2.7	3.0	4.1
3	1.0	1.3	1.8	2.2	2.9	3.3	5.2
4	1.1	1.4	1.9	2.3	3.1	3.5	6.1
5	1.2	1.5	2.0	2.4	3.3	3.7	6.9
6	1.2	1.6	2.1	2.5	3.4	3.8	7.7
12	1.4	1.8	2.3	2.8	3.8	4.3	8.4
18	1.4	1.9	2.6	3.1	4.0	4.6	8.8
24	1.5	2.0	2.7	3.2	4.2	4.8	8.9
48	1.8	2.3	3.2	3.7	4.9	5.6	9.9
72	2.0	2.5	3.4	4.1	5.3	6.1	10.4
96	2.1	2.7	3.6	4.3	5.6	6.4	10.6
RAINFALL BY ONE-HOUR INCREMENTS DURING MAXIMUM 6-HOUR ACCUMULATION							
0-1	0.8	1.1	1.4	1.7	2.3	2.5	2.9
1-2	0.1	0.1	0.3	0.2	0.4	0.5	1.2
2-3	0.1	0.1	0.1	0.3	0.2	0.3	1.1
3-4	0.1	0.1	0.1	0.1	0.2	0.2	0.9
4-5	0.1	0.1	0.1	0.1	0.2	0.2	0.8
5-6	0.0	0.1	0.1	0.1	0.1	0.1	0.8
RAINFALL BY 6-HOUR INCREMENTS DURING MAXIMUM 24-HOUR ACCUMULATION							
0-6	1.2	1.6	2.1	2.5	3.4	3.8	7.7
6-12	0.2	0.2	0.2	0.3	0.4	0.5	0.7
12-18	0.0	0.1	0.3	0.3	0.2	0.3	0.4
18-24	0.1	0.1	0.1	0.1	0.2	0.2	0.1
RAINFALL BY 24-HOUR INCREMENTS DURING MAXIMUM 96-HOUR ACCUMULATION							
0-24	1.5	2.0	2.7	3.2	4.2	4.8	8.9
24-48	0.3	0.3	0.5	0.5	0.7	0.8	1.0
48-72	0.2	0.2	0.2	0.4	0.4	0.5	0.5
72-96	0.1	0.2	0.2	0.2	0.3	0.3	0.2

Sources:

1. U.S. Weather Bureau Technical Publication No. 40
2. Minot DM2, Interior Drainage

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

RAINFALL DATA
DEPTH - DURATION - FREQUENCY

100 PERCENT HYPOTHETICAL HYETOGRAPH

RAINFALL AND RAINFALL EXCESS

LAST HOUR OF PERIOD	INCREMENTAL RAINFALL (INCHES)	ACCUMULATIVE RAINFALL (INCHES)	PERCENT SURFACE RUNOFF	INCREMENTAL RAINFALL EXCESS (INCHES)	ACCUMULATIVE RAINFALL EXCESS (INCHES)
24.00	.10	.10	20.00	.02	.02
48.00	.20	.30	25.00	.05	.07
72.00	.30	.60	30.00	.09	.16
78.00	.10	.70	40.00	.04	.20
84.00	.00	.70	50.00	.00	.20
90.00	.20	.90	70.00	.14	.34
90.50	.00	.90	72.22	.00	.34
91.00	.00	.90	74.63	.00	.34
91.50	.07	.97	77.03	.05	.40
92.00	.03	1.00	79.44	.02	.42
92.50	.07	1.07	81.85	.06	.48
93.00	.03	1.10	84.26	.03	.50
93.50	.07	1.17	86.67	.06	.56
94.00	.03	1.20	89.07	.03	.59
94.50	.07	1.27	91.48	.06	.65
95.00	.03	1.30	93.89	.03	.68
95.50	.53	1.83	96.30	.51	1.19
96.00	.27	2.10	98.71	.27	1.46

Source:

1. U.S. Department of Commerce, Weather Bureau Technical Paper Nos. 40 and 49.

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

HYPOTHETICAL HYETOGRAPH
100 PERCENT EXCEEDENCE INTERVAL

SAFETY PAYS

50 PERCENT HYPOTHETICAL HYETOGRAPH

RAINFALL AND RAINFALL EXCESS

LAST HOUR OF PERIOD	INCREMENTAL RAINFALL (INCHES)	ACCUMULATIVE RAINFALL (INCHES)	PERCENT SURFACE RUNOFF	INCREMENTAL RAINFALL EXCESS (INCHES)	ACCUMULATIVE RAINFALL EXCESS (INCHES)
24.00	.20	.20	20.00	.04	.04
48.00	.20	.40	25.00	.05	.09
72.00	.30	.70	30.00	.09	.18
78.00	.10	.80	40.00	.04	.22
84.00	.10	.90	50.00	.05	.27
90.00	.20	1.10	70.00	.14	.41
90.50	.07	1.17	72.22	.05	.46
91.00	.03	1.20	74.63	.02	.48
91.50	.07	1.27	77.03	.05	.53
92.00	.03	1.30	79.44	.03	.56
92.50	.07	1.37	81.85	.05	.62
93.00	.03	1.40	84.26	.03	.64
93.50	.07	1.47	86.67	.06	.70
94.00	.03	1.50	89.07	.03	.73
94.50	.07	1.57	91.48	.06	.79
95.00	.03	1.60	93.89	.03	.82
95.50	.73	2.33	96.30	.70	1.53
96.00	.37	2.70	98.71	.36	1.89

Source:

1. U.S. Department of Commerce, Weather Bureau Technical Paper Nos. 40 and 49.

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

SAFETY PAYS

HYPOTHETICAL HYETOGRAPH
50 PERCENT EXCEEDENCE INTERVAL

20 PERCENT HYPOTHETICAL HYETOGRAPH

RAINFALL AND RAINFALL EXCESS

LAST HOUR OF PERIOD	INCREMENTAL RAINFALL (INCHES)	ACCUMULATIVE RAINFALL (INCHES)	PERCENT SURFACE RUNOFF	INCREMENTAL RAINFALL EXCESS (INCHES)	ACCUMULATIVE RAINFALL EXCESS (INCHES)
24.00	.10	.10	20.00	.02	.02
48.00	.30	.40	25.00	.07	.09
72.00	.50	.90	30.00	.15	.25
78.00	.10	1.00	40.00	.04	.29
84.00	.20	1.20	50.00	.10	.38
90.00	.30	1.50	70.00	.21	.59
90.50	.07	1.57	72.22	.05	.64
91.00	.03	1.60	74.63	.02	.67
91.50	.07	1.67	77.03	.05	.72
92.00	.03	1.70	79.44	.03	.75
92.50	.07	1.77	81.85	.05	.80
93.00	.03	1.80	84.26	.03	.83
93.50	.07	1.87	86.67	.06	.89
94.00	.03	1.90	89.07	.03	.92
94.50	.20	2.10	91.48	.18	1.10
95.00	.10	2.20	93.89	.09	1.19
95.50	.94	3.14	96.30	.90	2.10
96.00	.46	3.60	98.71	.46	2.55

Source:

1. U.S. Department of Commerce, Weather Bureau Technical Paper Nos. 40 and 49.

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

HYPOTHETICAL HYETOGRAPH
20 PERCENT EXCEEDENCE INTERVAL

SAFETY PAYS

10 PERCENT HYPOTHETICAL HYETOGRAPH

RAINFALL AND RAINFALL EXCESS

LAST HOUR OF PERIOD	INCREMENTAL RAINFALL (INCHES)	ACCUMULATIVE RAINFALL (INCHES)	PERCENT SURFACE RUNOFF	INCREMENTAL RAINFALL EXCESS (INCHES)	ACCUMULATIVE RAINFALL EXCESS (INCHES)
24.00	.20	.20	20.00	.04	.04
48.00	.40	.60	25.00	.10	.14
72.00	.50	1.10	30.00	.15	.29
78.00	.10	1.20	40.00	.04	.33
84.00	.30	1.50	50.00	.15	.48
90.00	.30	1.80	70.00	.21	.69
90.50	.07	1.87	72.22	.05	.74
91.00	.03	1.90	74.63	.02	.76
91.50	.07	1.97	77.03	.05	.81
92.00	.03	2.00	79.44	.03	.84
92.50	.07	2.07	81.85	.05	.90
93.00	.03	2.10	84.26	.03	.92
93.50	.13	2.23	86.67	.12	1.04
94.00	.07	2.30	89.07	.06	1.10
94.50	.20	2.50	91.48	.18	1.28
95.00	.10	2.60	93.89	.09	1.38
95.50	1.13	3.73	96.30	1.09	2.47
96.00	.57	4.30	98.71	.56	3.03

Source:

1. U.S. Department of Commerce, Weather Bureau Technical Paper Nos. 40 and 49.

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

SAFETY PAYS

HYPOTHETICAL HYETOGRAPH
10 PERCENT EXCEEDENCE INTERVAL

2 PERCENT HYPOTHETICAL HYETOGRAPH

RAINFALL AND RAINFALL EXCESS

LAST HOUR OF PERIOD	INCREMENTAL RAINFALL (INCHES)	ACCUMULATIVE RAINFALL (INCHES)	PERCENT SURFACE RUNOFF	INCREMENTAL RAINFALL EXCESS (INCHES)	ACCUMULATIVE RAINFALL EXCESS (INCHES)
24.00	.30	.30	20.00	.06	.06
48.00	.40	.70	25.00	.10	.16
72.00	.70	1.40	30.00	.21	.37
78.00	.20	1.60	40.00	.08	.45
84.00	.20	1.80	50.00	.10	.55
90.00	.40	2.20	70.00	.28	.83
90.50	.07	2.27	72.22	.05	.88
91.00	.03	2.30	74.63	.02	.90
91.50	.13	2.43	77.03	.10	1.01
92.00	.07	2.50	79.44	.05	1.06
92.50	.13	2.63	81.85	.11	1.17
93.00	.07	2.70	84.26	.06	1.22
93.50	.13	2.83	86.67	.12	1.34
94.00	.07	2.90	89.07	.06	1.40
94.50	.27	3.17	91.48	.24	1.64
95.00	.13	3.30	93.89	.13	1.77
95.50	1.53	4.83	96.30	1.48	3.24
96.00	.77	5.60	98.71	.76	4.00

Source:

1. U.S. Department of Commerce, Weather Bureau Technical Paper Nos. 40 and 49.

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

HYPOTHETICAL HYETOGRAPH
2 PERCENT EXCEEDENCE INTERVAL
PLATE A-96

1 PERCENT HYPOTHETICAL HYETOGRAPH

RAINFALL AND RAINFALL EXCESS

LAST HOUR OF PERIOD	INCREMENTAL RAINFALL (INCHES)	ACCUMULATIVE RAINFALL (INCHES)	PERCENT SURFACE RUNOFF	INCREMENTAL RAINFALL EXCESS (INCHES)	ACCUMULATIVE RAINFALL EXCESS (INCHES)
24.00	.30	.30	20.00	.06	.06
48.00	.50	.80	25.00	.13	.19
72.00	.80	1.60	30.00	.24	.42
78.00	.20	1.80	40.00	.08	.50
84.00	.30	2.10	50.00	.15	.65
90.00	.50	2.60	70.00	.35	1.01
90.50	.07	2.67	72.22	.05	1.05
91.00	.03	2.70	74.63	.02	1.08
91.50	.13	2.83	77.03	.10	1.18
92.00	.07	2.90	79.44	.05	1.23
92.50	.13	3.03	81.85	.11	1.34
93.00	.07	3.10	84.26	.06	1.40
93.50	.20	3.30	86.67	.17	1.57
94.00	.10	3.40	89.07	.09	1.66
94.50	.33	3.73	91.48	.30	1.97
95.00	.17	3.90	93.89	.16	2.12
95.50	1.67	5.57	96.30	1.60	3.73
96.00	.83	6.40	98.71	.82	4.55

Source:

1. U.S. Department of Commerce, Weather Bureau Technical Paper Nos. 40 and 49.

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

HYPOTHETICAL HYETOGRAPH
1 PERCENT EXCEEDENCE INTERVAL
PLATE A-97

STANDARD PROJECT STORM

HYPOTHETICAL HYETOGRAPH

RAINFALL AND RAINFALL EXCESS

LAST HOUR OF PERIOD	INCREMENTAL RAINFALL (INCHES)	ACCUMULATIVE RAINFALL (INCHES)	PERCENT SURFACE RUNOFF	INCREMENTAL RAINFALL EXCESS (INCHES)	ACCUMULATIVE RAINFALL EXCESS (INCHES)
24.00	.20	.20	20.00	.04	.04
48.00	.50	.70	25.00	.13	.17
72.00	1.00	1.70	30.00	.30	.47
78.00	.10	1.80	40.00	.04	.51
84.00	.40	2.20	50.00	.20	.70
90.00	.70	2.90	70.00	.49	1.20
90.50	.53	3.43	72.22	.38	1.58
91.00	.27	3.70	74.63	.20	1.78
91.50	.53	4.23	77.03	.41	2.19
92.00	.27	4.50	79.44	.21	2.40
92.50	.60	5.10	81.85	.49	2.89
93.00	.30	5.40	84.26	.25	3.15
93.50	.73	6.13	86.67	.63	3.78
94.00	.37	6.50	89.07	.33	4.11
94.50	.80	7.30	91.48	.73	4.84
95.00	.40	7.70	93.89	.38	5.22
95.50	1.93	9.63	96.30	1.86	7.07
96.00	.97	10.60	98.71	.96	8.03

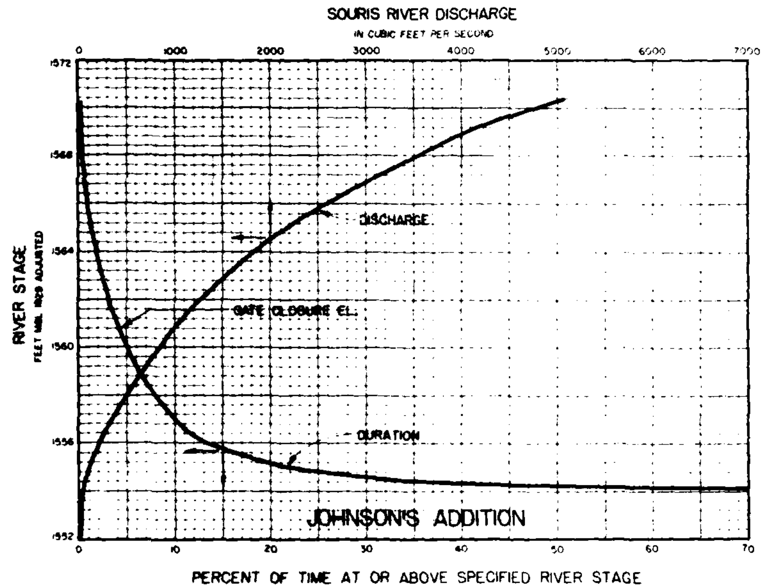
Source:

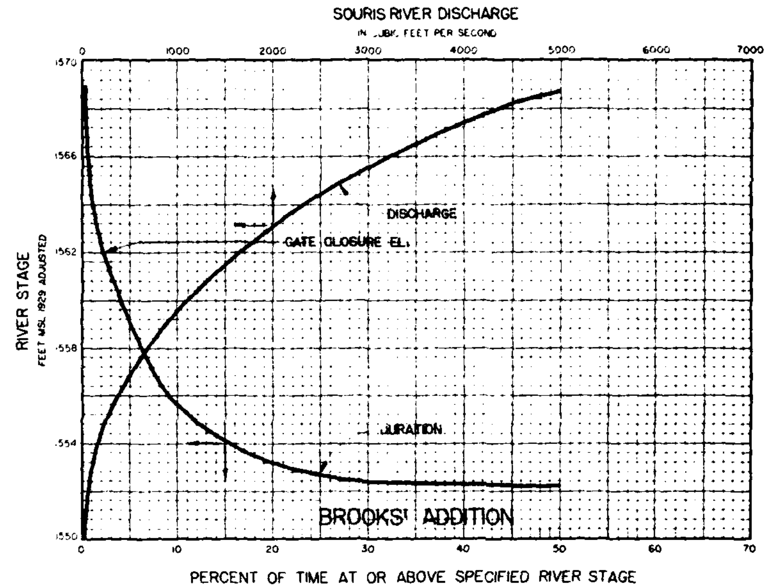
1. U.S. Department of Commerce, Weather Bureau Technical Paper Nos. 40 and 49.

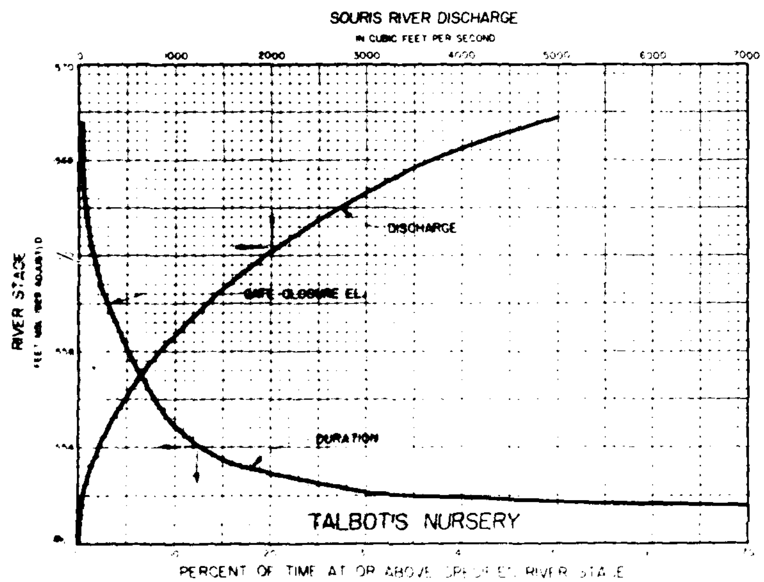
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

HYPOTHETICAL HYETOGRAPH
STANDARD PROJECT STORM

PLATE A-98







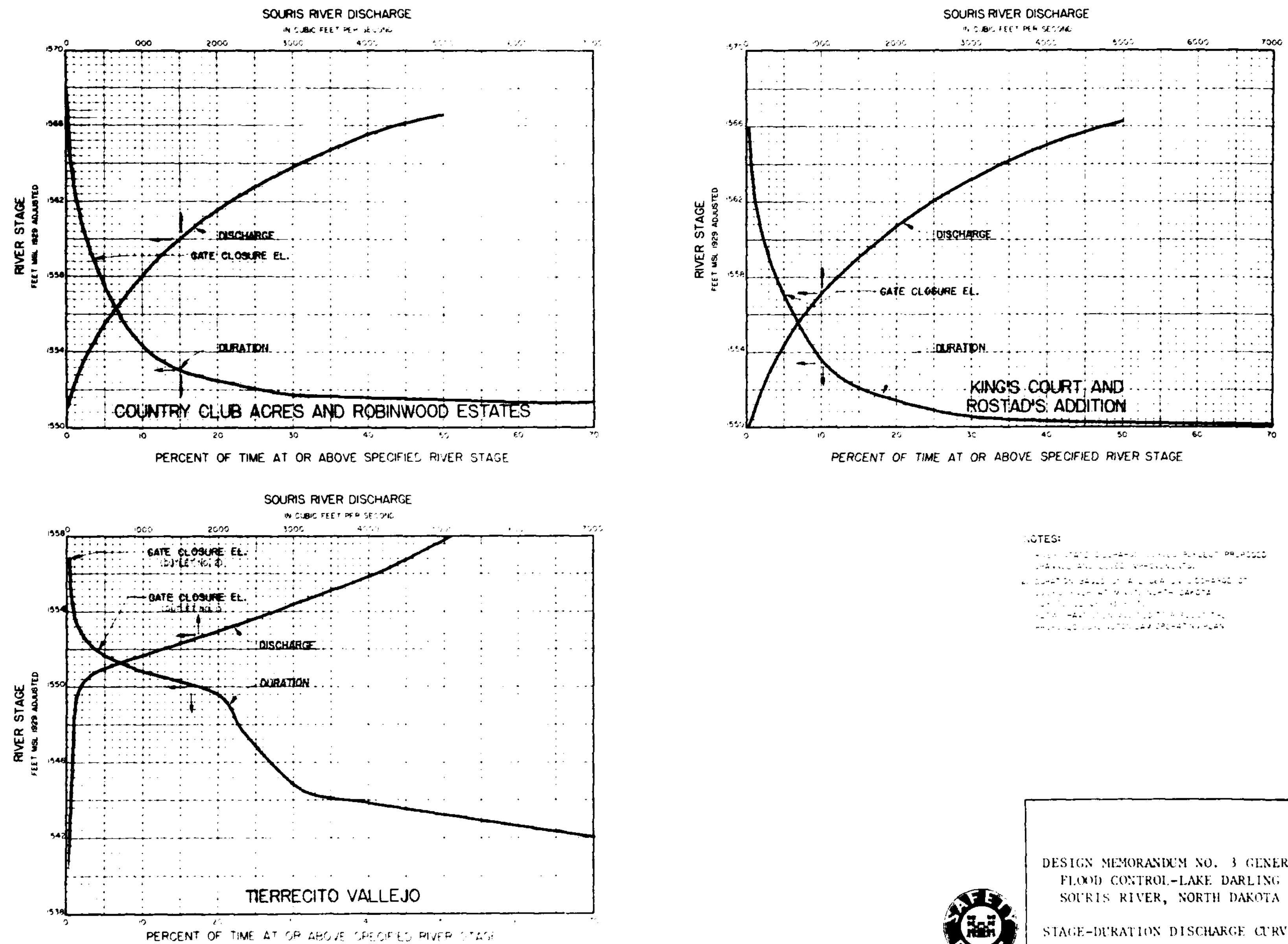
NOTES:

1. RIVER STAGE DISCHARGE CURVES REFLECT PROPOSED CHANNEL AND LEVEE IMPROVEMENTS.
2. DURATION BASED ON ALL SEASON DISCHARGE OF SOURIS RIVER AT MINOT, NORTH DAKOTA FOR PERIOD OF 1937-1975. FLOWS HAVE BEEN MODIFIED TO REFLECT THE PROPOSED BURLINGTON DAM OPERATING PLAN.

DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

STAGE-DURATION DISCHARGE CURVES

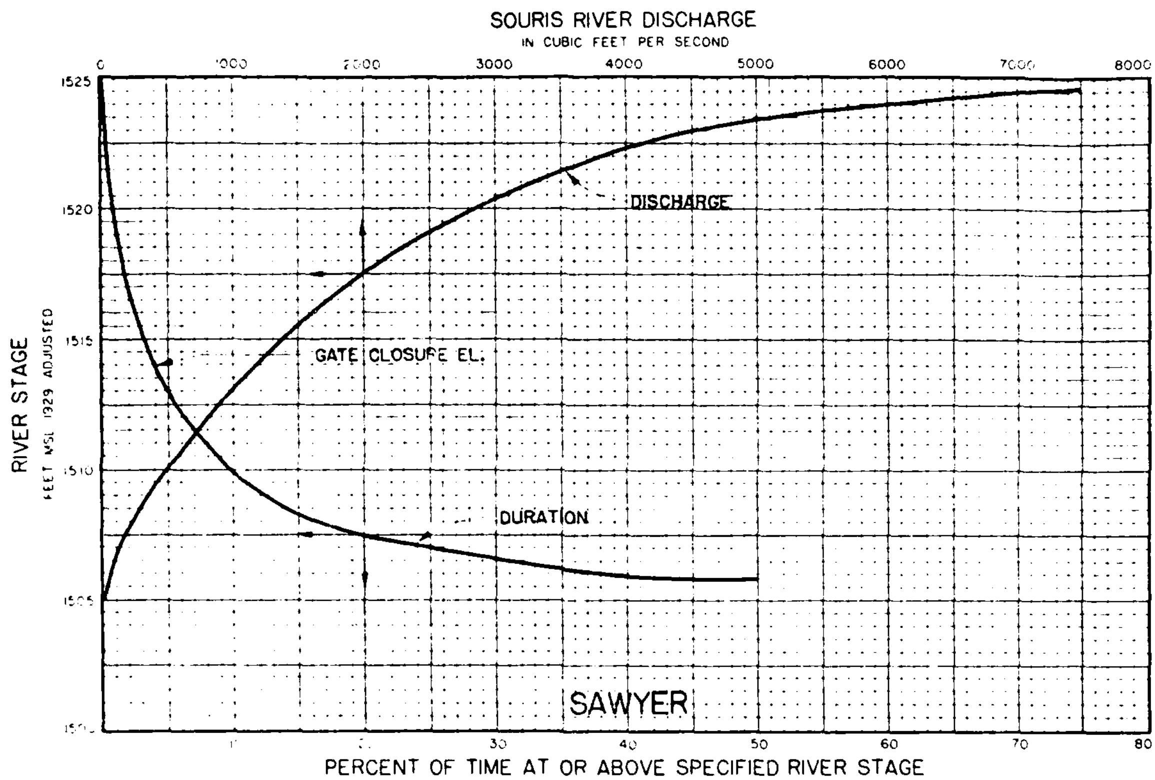
PLATE NO. 1-99



DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL-LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

STAGE-DURATION DISCHARGE CURVES

PLATE NO. A-100



DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

STAGE-DURATION DISCHARGE CURVES

PLATE A-101

APPENDIX C

ECONOMIC ANALYSIS

APPENDIX C

ECONOMIC ANALYSIS

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APPENDIX C

ECONOMIC ANALYSIS

INTRODUCTION

This appendix presents a limited reevaluation of economic flood damages in the Souris River basin. Conditions of development are those present as of October 1982. Price levels used for the analysis are October 1982. Benefits were updated to October 1983 price levels to allow for comparison with costs using the same index factors used to prepare the fiscal year 1985 budget testimony for Congress. The applicable interest rate is 5 1/8 percent.

The benefit analysis is for the proposed 4-foot raise of Lake Darling Dam and those elements necessary to operate the facility. For all areas but Velva, additional measures to protect downstream areas for flows greater than 5,000 cfs (cubic feet per second) were not incrementally justified. A plan for Velva was formulated in *Design Memorandum No. 4, Velva Improvements, Lake Darling Flood Control Project, Souris River, North Dakota, November 1982* and will only be summarized here.

ECONOMIC BASE STUDY

Economic and demographic data in this base study were used to evaluate flood losses sustained by floodplain residents, business firms, and the related public facilities and services in the study area. The study area includes the urban areas of Minot, Velva, Burlington, Logan and Sawyer and the rural areas from the southern boundary of Des Lacs National Wildlife Refuge to the southern boundary of the J. Clark Salyer National Wildlife Refuge. The magnitude of flood damages and flood damage reduction benefits attributable to future growth and development was estimated from income data. Major sources of data included U.S. Bureau of the Census publications, the Souris-Red Rainy River Basins Comprehensive Study, and the 1980 economic projections prepared for the Water Resources Council by the Departments of Commerce and Agriculture (OBERS projections). Minot's economic prospects are considered in terms of the river basin, the trade area, and the region of which Minot is the center.

The Minot Economic Area as delineated in 1980 by the Office of Business Economics of the U.S. Department of Commerce comprises Minot and the surrounding 12 counties of North Dakota: Bottineau, Burke, Divide, McHenry, McKenzie, McLean, Mountrail, Pierce, Renville, Rolette, Ward and Williams; and 4 counties of Montana: Richland, Roosevelt, Sheridan and Wibaux. An OBE economic area represents a fairly closed trade area in which the number and type of establishments are bounded by the transportation costs from outlying areas to competing centers. Each area approaches self-sufficiency with respect to trade activities and services which are most efficiently used in the vicinity of their production. The population of the 16-county area in 1980 was 183,620. Agriculture is its principal industry.

Minot, with a 1980 population of 32,843, is the major economic, cultural and transportation center for 15,000 square miles of north-

western North Dakota and northeastern Montana. The nearest comparable urban center is Bismarck, North Dakota, 114 miles south of Minot.

Minot's major economic industry is retailing. It's retail trade area covers nine counties and extends approximately 75 miles in all directions. Population in the nine-county retail trade area declined 2.85 percent from 114,843 in 1970 to 111,859 in 1980. During this period, Minot's increase in population was offset by the decline in the rural sections of the trade area. Long-term prospects for further growth in Minot's retail trade depend on natural increases in population, better transportation to expand the size of the trade area, and increased per capita income. Continued expansion of military and defense activities in the Minot vicinity would also favorably affect Minot's retail trade.

Minot's present development and prospects for future growth are closely related to the present conditions and future prospects of agriculture in the region. Agriculture is the Minot region's basic export industry and the foundation of the regional economy. Earnings from sales of farm products make possible most of the region's purchases of goods and services from other regions. Data pertaining to agriculture in the study area are presented in the following table.

Agricultural characteristics, Lake Darling project area, 1974 (1)

Characteristic	County					Total Project Area
	Ward	McHenry	Bottineau	Renville	Rolette	
Number of farms	1,425	1,156	1,192	547	628	4,948
Average size of farms	881	1,006	922	953	833	919
Market value of all farm products sold ($1,000)	55,080	34,252	50,319	23,187	20,998	183,836
Market value of all farm products sold per farm	38,652	29,630	42,214	42,389	33,437	118,040
Value of farmlands and buildings ($1,000)	236,145	117,399	268,537	99,085	96,349	817,515
Value of farmlands and buildings per acre	188	152	244	190	184	192
Value of machinery and equipment ($1,000)	52,077	35,744	45,796	22,246	21,489	177,352
Total value of farmlands, buildings, machinery and equipment ($1,000)	288,222	153,143	314,333	121,221	117,838	994,867
Farm products costs	27,361	19,324	23,106	10,988	10,973	91,752
Value of crops sold	46,109	24,202	46,563	21,350	17,907	156,131

(1) 1974 Census of Agriculture, U.S. Department of Commerce.

Between 1969 and 1974, the relative value to total value of crops increased from 73 to 84 percent with a corresponding increase in the value of livestock production. Wheat, hay, oats, flaxseed, barley and rye are the principal grain crops, with some corn and potatoes. In 1979, wheat production in the study area was 23.6 bushels per acre. The U.S. Department of Agriculture anticipates that crop yields in the study area will continue to increase, with the average yield of wheat per acre increasing to 31 bushels in the year 2000 and 37 bushels in 2020. Similar increases are anticipated for other grains.

Growth in per capita income reflects improvement in the economic well-being of an area. Historic and projected per capita income in 1980 dollars for the Minot Economic Area and for North Dakota were furnished by the Office of Business Economics, U.S. Department of Commerce (see the following table).

Money also comes into the region from expenditures for national defense. In contrast with a large and expanding agricultural output, the magnitude of future expenditures for the Minot Air Force Base cannot be foreseen.

Projections of per capita income - 1980 (1)

Item	Year 1950	1960	1970	1980	1985	1990	2000	2030
				Minot Economic Area				
Per capita income (1)	1,843	2,214	2,727	4,871	6,020	6,846	8,721	15,597
Per capita income index (1980=100)				100	124	141	179	320
				North Dakota				
Per capita income (1)			3,330	4,955	6,070	6,892	8,789	15,754
Per capita income index (1980=100)				100	123	139	177	318

(1) 1980 OBERS BEA Regional Projections, U.S. Department of Commerce.

Per capita income in the Minot economic area has increased from $2,727 in 1970 to $4,871 in 1980, an increase of 80 percent. During this period, per capita income in North Dakota increased by 49 percent. Because the growth of per capita income is expected to be greater in the Minot economic area than in North Dakota, the growth potential for Minot appears to be greater than the average for North Dakota.

Historic population data were obtained from the U.S. Bureau of the Census. Population projections were taken from Population Projections for Counties and Towns in the Souris Basin, 1980-2000, prepared by North Dakota State University for the Souris Basin Planning Council.

Minot, the largest city in the study area, is expected to have the highest rate of population growth in the basin. The 1980 population of 32,834 is expected to increase to 49,542 by the year 2035, an increase of 50.8 percent (see the following table). Ward County is expected to experience an increase in population of 47 percent during the same period.

Historic populations and population projections for project area

Community	Year (1)							
	1940	1950	1960	1970	1980	1985 (3)	2000 (3)	2035 (4)
Minot	16,577	22,032	30,290	32,290	32,843	34,800	38,184	49,542
Sawyer	271	264	390	373	417	434 (4)	451 (4)	494
Velva	1,027	1,170	1,330	1,241	1,101	1,167 (4)	1,284 (4)	1,743
Ward County (2)	34,981	34,782	47,072	58,560	58,392	60,200	70,745	85,797
Renville County	5,533	5,405	4,698	3,828	3,608	3,746	4,048	4,225

(1) Figures through 1980 are from the *1980 Census of the U.S.*, U.S. Dept. of Commerce.

(2) Includes a constant military population of 12,077 from 1980 to 2035.

(3) Population Projection for Counties and Towns in the Souris Basin, 1980-2000, by North Dakota State University, Minot, N.D. for Souris Basin Planning Council, 1981.

(4) Extrapolated.

In 1980, OBERS projected the 1990 population of the Minot economic area to be 201,298 for a "no change in share" trend, 198,455 for a "low change in share" trend, and 196,150 for a "moderate change in share" trend. The 1980 population was 183,620.

Total employment in Ward County, including Minot, increased from 10,317 in 1940 to 21,711 in 1980, an increase of 110 percent (see the following table). During this period, agricultural employment in Ward County declined from 3,487 to 1,362, a reduction of 61 percent, which reduced the rate of growth in total employment for Ward County. During the 1940-1980 period, employment increased significantly in construction; wholesale and retail trade; finance, insurance and real estate; and government. Except for the decline in the natural resource industries (agriculture, forestry, fisheries, and mining) and transportation, communications, and utilities, each industry's percentage share of total employment increased over the 40-year period.

Employment by industry, Ward County, North Dakota, 1940-1980

Industry	1940 (1)		1950 (1)		1960 (1)		1970 (2)		1980 (3)	
	Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total
Agriculture, forestry, fisheries and mining	3,487	33.8	2,923	22.6	2,086	11.9	1,586	9.1	1,362	6.3
Construction	274	2.7	785	6.1	1,241	7.1	1,040	6.0	1,533	7.1
Manufacturing	412	4.0	558	4.3	749	4.3	847	4.9	987	4.5
Transportation, communications, and utilities	1,098	10.6	1,809	14.0	1,810	10.4	1,649	9.5	2,059	9.5
Wholesale and retail trade	2,134	20.7	3,314	25.7	4,055	23.2	4,787	27.5	6,443	29.7
Finance, insurance and real estate	239	2.3	299	2.3	612	3.5	667	3.8	1,113	5.1
Services	2,239	21.7	2,605	20.2	3,932	22.5	3,867	22.2	3,618	16.7
Government	293	2.8	409	3.2	840	4.8	964	5.5	2,589	11.9
Industry not reported	141	1.4	201	1.5	234	1.4	256	1.5	548	2.5
Armed forces	0	0	13	0.1	1,907	10.9	1,744	10.0	1,459	6.7
Total	10,317	100.0	12,916	100.0	17,466	100.0	17,407	100.0	21,711	100.0

(1) Growth Patterns in Employment by County, 1940-1950 and 1950-1960, U.S. Department of Commerce, 1965.

(2) U.S. Bureau of Census data for 1970.

(3) Advance estimates of social, economic, and housing characteristics, 1980 Census of the U.S.

In 1980, 6.0 percent of the Ward County civilian labor force were unemployed. The labor force consists of persons who are working or actively seeking employment. Potential workers, such as married women and students, who would seek work if jobs were more abundant but who are not actively seeking employment, are not classified as part of the labor force.

Total employment in Minot increased from 5,537 in 1940 to 14,610 in 1980, an increase of 164 percent (see the following table). Major increases occurred in construction, services, and government. Between 1970 and 1980, total employment increased by 2,497 persons. In 1980, 6.3 percent of the civilian labor force were unemployed.

Employment by industry, Minot, North Dakota, 1940-1980

Industry	1940		1950		1960		1970		1980	
	Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total
Agriculture, forestry, fisheries, and Mining	93	1.7	267	3.1	220	2.0	166	1.4	270	1.8
Construction	220	4.0	613	7.1	937	8.4	681	5.6	871	6.0
Manufacturing	363	6.6	502	5.9	655	5.9	693	5.7	738	5.1
Transportation, communications, and utilities	916	16.5	1,489	17.4	1,512	13.6	1,314	10.8	1,502	10.3
Wholesale, retail trade	1,754	31.7	2,808	32.7	3,260	29.2	3,548	29.3	4,555	31.2
Finance, insurance, and real estate	212	3.8	283	3.3	592	5.3	533	4.4	849	5.8
Services	1,669	30.1	2,179	25.4	3,199	28.7	4,485	37.1	2,427	16.6
Government	223	4.0	323	3.8	622	5.6	693	5.7	1,848	12.6
Industry not reported	87	1.6	115	1.3	157	1.4			1,550	10.6
Total	5,537	100.0	8,579	100.0	11,154	100.0	12,113	100.0	14,610	100.0

Source: U.S. Bureau of the Census data.

Minot maintains a strong position as a trade and transportation center and its future in this respect seems assured by the size and resources of its trade area. Even though little employment growth is expected in the primary or basic producing industries, secondary industries growth is expected to continue increasing.

FLOOD DAMAGES - WITHOUT PROJECT

This section discusses the determination of flood damages under without project conditions. These conditions are 1982 development conditions. Because flood control is not an authorized purpose of Lake Darling Dam, it is assumed to provide no flood damage reduction. Flood damages are categorized as urban, rural, and transportation.

URBAN

Urban flood damages consist of losses to floodplain residents, businesses, institutions, and government agencies. Losses sustained by floodplain residents include physical damage to dwellings, contents, and yards; costs of evacuation to temporary quarters if borne by individuals; and costs of postflood cleanup. Business and institutional losses include physical damage to commercial, industrial, and institutional structures and their contents including merchandise, machinery, and equipment; costs of postflood cleanup; and lost wages. Flood expenditures by local, State and Federal agencies are considered public losses. They include the cost of repairing physical damage to streets, sidewalks, sewers, sewage treatment plants, water systems, parks, public schools, playgrounds, and other public property. Other public losses are costs of emergency measures, including overtime work by police and fire fighters, emergency aid to flood victims, suspension and restoration of utilities, and postflood debris removal.

The urban areas susceptible to flooding are the communities of Minot, Sawyer, and Velva; the area from Highway 2 through Logan; and the subdivisions of Johnson's Addition, Brook's Addition Talbot's Nursery, King's Court, Robinswood Estates and Country Club Acres, and Tierrecita Vallejo. The hydraulic, hydrologic, and economic information used to determine flood damages for these areas is summarized in the following table.

Information used to evaluate urban flood damges

Urban area	Reference Point (1)	Frequency-elevation information	Elevation-damage information (4)
Johnson's Addition (2)	151256	HEC2 water surface profiles	Updated economic curve
Brook's Addition	142850	HEC2 water surface profiles	Updated economic curve
Talbot's Nursery	135580	HEC2 water surface profiles	Updated economic curve
King's Court	124330	HEC2 water surface profiles	Updated economic curve
Robinswood Estates and Country Club Acres	132140	HEC2 water surface profiles	Updated economic curve
Tierrecita Vallejo	97280	HEC2 water surface profiles	Updated economic curve
Minot	72928(3)	Frequency-discharge and rating curves	Updated economic curve
Highway 2 through Logan	51146.00	HEC2 water surface profiles	Updated economic curve
Sawyer	23.61	HEC2 water surface profiles	Updated economic curve
Velva	38.60	Frequency-discharge and rating curves	Updated economic curve

(1) Cross section
(2) Johnson's Addition has been annexed by the city of Burlington; however, it is the only part of Burlington subject to flooding.
(3) Upstream side of footbridge near Main Street.
(4) Price levels of economic curves used in the 1977 Phase I GDM were updated.

Minot

Inside the Minot city limits, about 1,884 developed acres are in the 100-year floodplain. Residences account for over one-half the floodplain development. In 1982, the 100-year floodplain included 3,540 residences, 306 businesses, 1 theological institute, 5 elementary and 1 junior high school, 2 parks, 1 zoo, and the State Fairgrounds.

Damages from the 1973 development conditions elevation-damage curve were updated to October 1982 price levels using ENR (Engineering News Record) construction and building indexes. The elevation-damage relationship was then correlated with the without project frequency-discharge and discharge-elevation relationships for Minot using the EAD (Expected Annual Damage) computer program. The average annual damages at Minot without project, October 1982 price levels, 1973 development conditions are $4,629,100.

Growth in Minot from 1973 to 1982 was determined through a careful examination of building permits issued by the city during this period. Structure-by-structure damages were analyzed using the DDS (Depth Damage Survey) program. This program determines damages from the elevations of given flood frequencies at each structure. The EAD program annualized the damages. Average annual damages for interim growth at Minot are $49,600.

The following table summarizes average annual damages for Minot, 1982 development conditions.

Average annual without project damages Minot

Category	Amount
1973 development conditions	$4,629,100
Interim growth, 1973-1982	49,600
Total	$4,678,700

Velva

The without project discharge-frequency curve for the Souris River at Velva was correlated with discharge-elevation and elevation-damage curves presented in Design Memorandum No. 4, Velva Improvements, Lake Darling Flood Control Project, Souris River, North Dakota, November 1982. The EAD program computed the average annual damages at Velva to be $722,600.

Remaining Urban Areas

Damages at the remaining urban areas were updated to October 1982 price levels from elevation-damage curves for each area. No discernible growth has taken place in the 100-year floodplains of those areas. Frequency-elevation relationships were determined from water surface profiles for without project conditions. These two relationships were combined using the EAD program. Average annual damages for the remaining urban areas are given in the following table along with the damages for Minot and Velva.

Average annual damages without project, urban areas (1)

Urban area	Average annual damages Residential	Nonresidential (2)	Total
Johnson's Addition	$123,100		$123,100
Brook's Addition	39,400		39,400
Talbot's Nursery	19,200		19,200
King's Court	105,300		105,300
Robinswood Estates and Country Club Acres	204,600		204,600
Tierrecita Vallejo	12,200		12,200
Minot	1,497,200	$3,131,900	4,629,100
Highway 2 through Logan	24,600	10,100	34,700
Sawyer	21,600		21,600
Velva	317,900	404,700	722,600
Total	2,365,100	3,546,700	5,911,800

(1) 1982 development conditions.
(2) Commercial, industrial and public.

Future Growth

Floodplain ordinances prohibit construction of new nonflood-proofed structures in the floodplain. Thus, the only increase in damages will be due to the increase in the value of residential contents. This increase in value was estimated over the first 50 years of the project life (1985-2035) using the change in regional per capita income. No further growth was assumed for the second 50 years.

OBERS data (1980) projects per capita income in the Minot economic area will increase from $4,900 to $15,600 (1983-2035). This increase equals a compound growth rate of 2 1/4 percent per year. The present value of contents is estimated at 25 percent of structure value and by regulation cannot increase to more than 75 percent of structure value. This maximum value will be reached after 52 years. The following table shows how content value will increase.

Increase in residential content value

Growth rate of OBERS per capita income

Year	Per capita income
1983	$4,900
2035	15,600

$15,600÷$4,900 = 3.2 (in 52 years) = 2 1/4-percent annual growth rate.

Growth of residential content value, 2 1/4-percent annual growth rate

Year	Years from present	Growth index
1983	0	1.0
1985 (base year)	2	1.0
1990	7	1.2
2000	17	1.5
2010	27	1.8
2020	37	2.3
2030	49	3.0
2035	52	3.0

Growth will maximize in 2035.

Residential damages from the table on page C- were apportioned to structure value and contents value. The growth indexes were applied to the value of damages to residential contents to determine damages with future growth. The following table shows how future growth affects average annual urban residential damages.

Average annual without project urban residential damages, including future growth

Urban area	Category	Year 1982	Year 1985	Year 2000	Year 2035	Increase 1985-2030	Average annual equiva-lent factor	Average annual equiva-lent of increase	Total average annual damages
Index		1.0	1.0	1.5	3.0				
Johnson's Addition	Structure	$73,900	$73,900	$73,900	73,900				
	Contents	42,200	49,200	73,800	147,600				
	Total	123,100	123,100	147,700	221,500	$98,400	0.3243	$ 31,900	$155,000
Brook's Addition	Structure	23,600	23,600	23,600	23,600				
	Contents	15,800	15,800	23,700	47,700				
	Total	39,400	39,400	47,300	71,000	31,600	0.3243	10,200	49,600
Talbot's Nursery	Structure	11,500	11,500	11,500	11,500				
	Contents	7,700	7,700	11,600	23,100				
	Total	19,200	19,200	23,100	34,600	15,400	0.3243	5,000	24,200
King's Court	Structure	63,200	63,200	63,200	63,200				
	Contents	42,100	42,100	63,200	126,300				
	Total	105,300	105,300	126,400	189,500	84,200	0.3243	27,300	132,600
Robinswood Estates and Country Club Acres	Structure	122,800	122,800	122,800	122,800				
	Contents	81,800	81,800	122,700	245,400				
	Total	204,600	204,600	145,500	368,200	163,600	0.3243	53,100	257,700
Tierrecita Vallejo	Structure	7,300	7,300	7,300	7,300				
	Contents	4,900	4,900	7,400	14,600				
	Total	12,200	12,200	14,700	21,900	9,700	0.3243	3,100	15,300
Minot	Structure	898,300	898,300	898,300	898,300				
	Contents	598,900	598,900	898,400	1,796,700				
	Total	1,497,200	1,497,200	1,796,700	2,695,000	1,197,800	0.3243	388,400	1,885,600
Highway 2 through Logan	Structure	14,800	14,800	14,800	14,800				
	Contents	9,800	9,800	14,700	29,400				
	Total	24,600	24,600	29,500	44,200	19,600	0.3243	6,400	31,000
Sawyer	Structure	13,000	13,000	13,000	13,000				
	Contents	8,600	8,600	12,900	25,800				
	Total	21,600	21,600	35,800	38,700	17,100	0.3243	5,500	27,100
Velva	Structure	190,800	190,800	190,800	190,800				
	Contents	127,100	127,100	190,700	381,300				
	Total	317,900	317,900	381,500	572,100	254,200	0.3243	82,400	400,300
Total		2,365,100	2,356,100	2,748,200	4,256,700	1,891,600		613,300	2,978,400

Summary

The sum of average annual damages for residential including future growth and for nonresidential is the average annual urban damages (see the following table).

Total average annual urban damages (includes future growth)

	Average annual damages		
Urban area	Residential	Nonresidential	Total
Johnson's Addition	$155,000		155,000
Brook's Addition	49,600		49,600
Talbot's Nursery	24,200		24,200
King's Court	132,600		132,600
Robinswood Estates and Country Club Acres	257,700		257,700
Tierrecita Vallejo	15,300		15,300
Minot	1,885,600	$3,131,900	5,017,500
Highway 2 through Logan	31,000	10,100	41,100
Sawyer	27,100		27,100
Velva	400,300	404,700	805,000
Total	2,978,400	3,546,700	6,525,100

RURAL

Flood damages in rural areas include damages to crops, cropland, livestock, fences, farmbuildings and contents, residences, and commercial and public structures. For this analysis, damages are categorized as agricultural; other agricultural; and residential, commercial, and public.

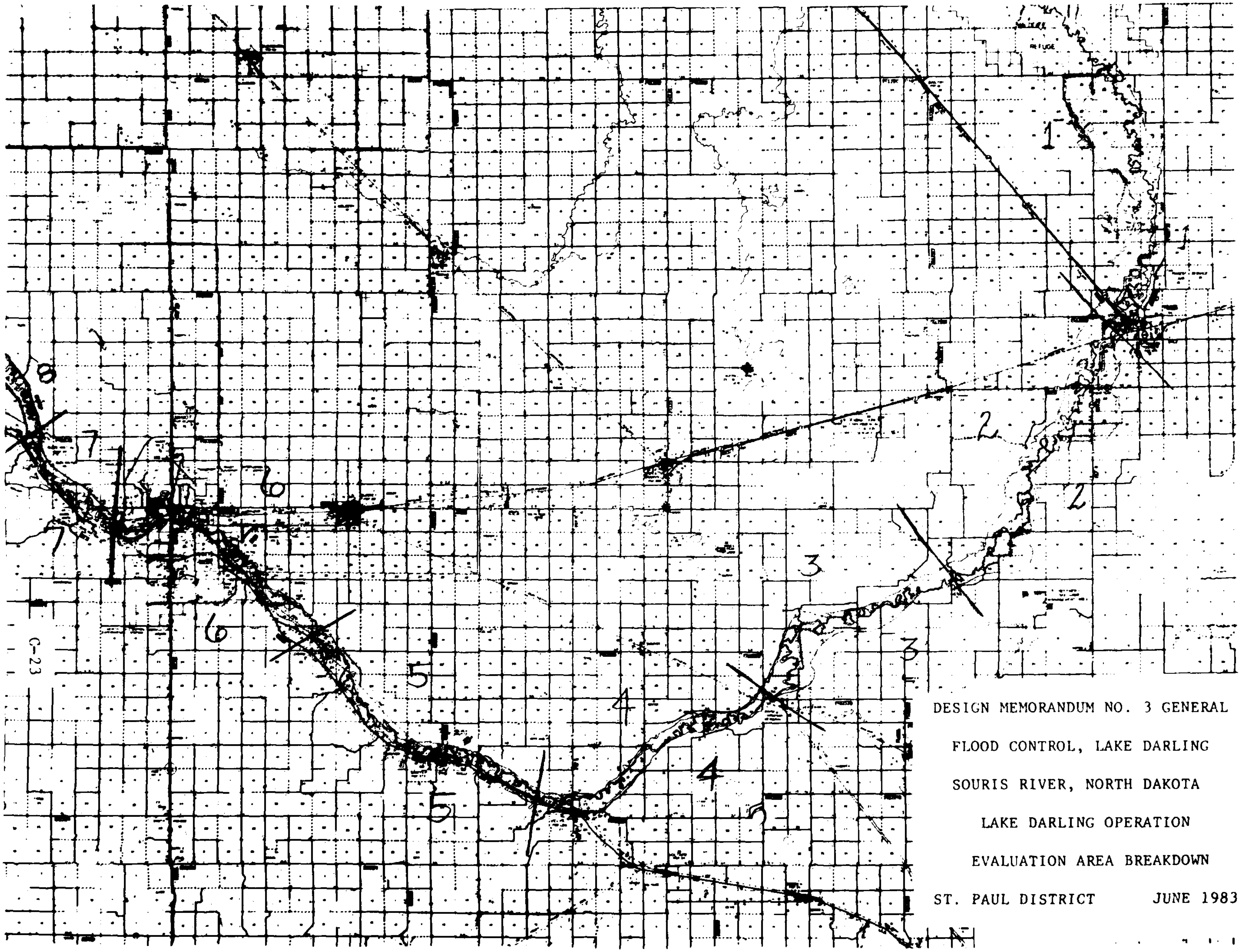
The rural portions of the study area were divided into seven evaluation areas. A brief description of each area and a map are presented in the following table and figure, respectively.

Rural evaluation areas

Number	Description	Location (cross sections)	Channel capacity (cfs)
1	Towner to State Road 17, J. Clark Salyer Refuge	131-149	100
2	Wintering River inlet to Towner	92-131	500
3	Verendrye to the Wintering River inlet	73.5-92	1,000
4	Velva to Verendrye	38.6-73.5	1,500
5	Logan to Velva	8.0-38.6	2,500
6	Minot to Logan	56670-8.0	2,500
7	Burlington to Minot	154250-111000	2,500
8	Southern boundary of Des Lacs National Wildlife Refuge to Burlington	22154250	2,500

Agricultural

Agricultural damages take the form of reduced crop yields which lead to lower incomes and higher production costs to grow the crop affected by a flood. Included are costs for additional



DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL, LAKE DARLING

SOURIS RIVER, NORTH DAKOTA

LAKE DARLING OPERATION

EVALUATION AREA BREAKDOWN

ST. PAUL DISTRICT JUNE 1983

fertilizer to replace lost fertilizer, additional herbicides to fight a more severe weed problem, additional seed to ensure adequate germination, and repetition of some tilling.

Average annual agricultural damages are computed by multiplying the crop damage per acre by the average annual acres flooded. Crop damage per acre is determined using "The Computerized Agricultural Crop Flood Damage Assessment System" computer program developed by the Vicksburg District.

The program uses three input files:

1. Area flooded hydrographs.
2. Flood damage tables.
3. General input data.

The flood damage tables are the crop budgets for initial and replant or substitute crops. They include the dates on which farming operations are performed and the duration of flooding which will cause damages.

General input data include land use, yields, dry-out periods, gross and net revenues, and sequence and timing of replants if the initial crop is lost. Yield, revenue, and land use data for the area are presented in the following table.

Gross and net revenues for initial crops

Crop	Yield per acre	Price per unit	Gross Revenue	Costs	Net revenue
Wheat	40 bushels	$4.34	$173.60	$64.70	$108.90
Barley	45 bushels	2.54	114.30	69.07	45.23
Oats	60 bushels	1.72	103.20	62.96	40.24
Sun-flowers	13 cwt	12.22	158.86	107.52	51.34

Land use also includes hayland. More hay is grown in areas more frequently flooded because it is more tolerant of spring

flooding. Thus, more hay is grown in downstream areas where the channel capacity is lowest. Two types of hay are grown: brome grass ($60 per acre) and alfalfa ($100 per acre).

Land use was determined by sampling individual farms. In some areas land use was fairly homogeneous; the others had two general patterns. Crop damages were computed for these different types of land use.

The following steps illustrate how crop damages are determined for a 200-acre parcel flooded for 10 days ending on 10 April:

1. Check duration to see if it is long enough to cause damages.

2. Add dry-out time (if it were 25 days, the farmer could get in the field by 5 May).

3. Allocate acres flooded to land use (e.g., 100 acres wheat, 50 acres sunflowers, and 50 acres other uses).

4. Check "in field" date against initial planting dates (e.g., initial planting dates for wheat and sunflowers are 20 April and 7 May).

5. Default to next crop (reduced-yield wheat, initial sunflowers could still be planted).

The program's output expresses damages by historic event and on a per-acre basis. The following table shows land use types in the basin and corresponding damage per acre figures.

Flood damages per acre by land use

Evaluation Area	Land use type	Crop percentage								Damage per acre
		Wheat	Barley	Oats	Sunflowers	Brome	Alfalfa	Other	Total	
1	1	2				60	25	13	100	$4.82
	2	8				40	14	38	100	7.85
2		12				52	25	11	100	10.25
3	1	40	5	10	12	18		15	100	28.75
	2	10				40	20	30	100	4.77
4		30	5	10	5		16	34	100	15.73
5	1	45	5	15	5		10	20	100	24.02
	2	20	4	7	3		14	52	100	11.57
6		20	5	5		10		60	100	7.02
7	1	25	10	5				60	100	9.19
	2	10	5					85	100	3.46
8	1	10				30	10	50	100	2.70
	2	20	5			20		55	100	6.17

Acres flooded at selected frequencies were determined on a parcel-by-parcel basis using the DDS (Depth Damage System) program. Frequency-elevation relationships at selected cross sections from HEC2 water surface profiles were correlated with elevation-damage relationships for each parcel. Acres flooded were totaled by evaluation area and the frequency-acres flooded information was input to the EAD (Expected Annual Damage) program. Average annual acres flooded multiplied by the damages per acre are the average annual agricultural damages (see the following table). Future agricultural damages were not evaluated for this report.

Average annual damages without project, agricultural

Evaluation Area	Land use Type	Land use Percent	Damage per acre	Average annual acres flooded	Average annual damages
1	1	67	$4.82	1,229	$5,921
	2	33	7.85	614	4,821
		100		1,843	10,742
2		100	10.25	4,659	47,752
3	1	50	28.75	433	12,456
	2	50	4.77	433	2,067
		100		866	14,523
4		100	15.73	631	9,931
5	1	50	24.02	151	3,622
	2	50	11.57	151	1,745
		100		302	5,367
6		100	7.02	217	1,525
7	1	50	9.19	108	994
	2	50	3.46	108	374
		100			1,368
8	1	67	2.70	75	204
	2	33	6.17	38	233
		100		113	437
Total					91,645

Other Agricultural

Other agricultural damages are all losses sustained by farmers other than crop damages: livestock losses and damage to farmstead structures, farm machinery, stored crops and hay, and fences and corrals. Damages to farm residences are normally included in this category, but they are included in the rural residential damages for this analysis.

Elevation-damage relationships were developed for each parcel. This information was compared to frequency-elevation information from HEC2 water surface profiles using the DDS program. The resulting frequency-damage relationship was converted to average annual damages using the EAD program. Average annual other agricultural damages are shown in the following table. Future other agricultural damages were not evaluated for this report.

Average annual without project damages, other agricultural

Evaluation area	Amount
1	$9,849
2	9,695
3	14,488
4	11,135
5	10,457
6	9,752
7	9,353
8	1,533
Total	76,262

Residential and Nonresidential Structures

Damages to these rural structures were computed on a structure-by-structure basis using the DDS program. Frequency-elevation information from HEC2 water surface profiles was combined with information on the structures' replacement values, first- and ground-floor elevations, and location by cross section. The resulting frequency-damage information was converted to EAD input and average annual damages were determined (see the following table).

Average annual without project damages, rural residential and nonresidential structures

Evaluation area	Average annual damages		
	Residential	Nonresidential	Total
1	$18,192		$18,192
2	50,564		50,564
3	26,038		26,038
4	42,999		42,999
5	46,341		46,341
6	53,755	$161,264	215,019
7	47,661	47,661	95,322
8	2,082		2,082
Total	287,632	208,925	496,557

As with urban residential damages, rural residential damages will increase because the value of residential contents will increase. The same process was used to account for this future growth as that used for urban residential damages. The following table gives average annual rural residential damages with future growth.

Average annual without project rural residential damages, including future growth

Evaluation area	Category	1982	Year 1985	2035	Increase 1985-2030	Average annual equivalent factor	Average annual equivalent of increase	Total average annual damages
1	Structure	$10,915	$10,915	$10,915				
	Contents	7,277	7,277	21,831				
	Total	18,192	18,192	32,746	$14,554	0.3243	$4,720	$22,912
2	Structure	30,338	30,338	30,338				
	Contents	20,226	20,226	60,678				
	Total	50,564	50,564	91,016	40,452	0.3243	13,119	63,683
3	Structure	15,623	15,623	15,623				
	Contents	10,415	10,415	31,245				
	Total	26,038	26,038	46,868	20,830	0.3243	6,755	32,793
4	Structure	25,799	25,799	25,799				
	Contents	17,200	17,200	51,600				
	Total	42,999	42,999	77,399	34,400	0.3243	11,156	54,155
5	Structure	27,805	27,805	27,805				
	Contents	18,536	18,536	55,608				
	Total	46,341	46,341	83,413	37,072	0.3243	12,022	58,363
6	Structure	32,253	32,253	32,253				
	Contents	21,502	21,502	64,506				
	Total	53,755	53,755	96,759	43,004	0.3243	13,946	67,701
7	Structure	28,597	28,597	28,597				
	Contents	19,064	19,064	57,192				
	Total	47,661	47,661	85,789	38,128	0.3243	12,365	60,026
8	Structure	1,249	1,249	1,249				
	Contents	833	833	2,399				
	Total	2,082	2,082	3,748	1,666	0.3243	540	2,622
Total		287,632	287,632	517,738	230,106		74,623	362,255

Average annual residential and nonresidential damages are the sum of nonresidential damages and residential damages including future growth (see the following table).

Without project average annual residential and nonresidential damages (including future growth)

Evaluation area	Average annual damages		
	Residential	Nonresidential	Total
1	$22,912		$22,912
2	63,683		63,683
3	32,793		32,793
4	54,155		54,155
5	58,363		58,363
6	67,701	$161,264	228,965
7	60,026	47,661	107,687
8	2,622		2,622
Total	362,255	208,925	571,180

Summary

Total average annual without project damages for the rural areas are the sum of the average annual agricultural, other agricultural, and residential and nonresidential damages. They are summarized in the following table.

Total average annual without project rural damages
(including future growth)

Evaluation area	Average annual damages: Agricultural	Other agriculture	Residential and nonresidential	Total
1	$ 10,742	$9,849	$22,912	$43,503
2	47,752	9,695	63,683	121,130
3	14,523	14,488	32,793	61,804
4	9,931	11,135	54,155	75,221
5	5,367	10,457	58,363	74,187
6	1,525	9,752	228,965	240,242
7	1,368	9,353	107,687	118,408
8	437	1,533	2,622	4,592
Total	91,645	76,262	571,180	739,087

Transportation

Transportation damages are damages to rural roads and bridges and include costs of repairing damaged bridges and culverts and restoring surface material washed from road grades and washouts at bridge and culvert approaches. Data on these damages were obtained from county and township officials. From the above damage estimates and zero-damage discharge, a discharge-damage curve was drawn. By relating this curve to the frequency of independent instantaneous peak discharge curve, the frequency-damage curve was developed. From this curve, the average annual damages were calculated.

Average annual without project transportation damages

Evaluation area	Acres flooded	Damage per acre	Damages
1	1,842.53	$12.30	$22,700
2	4,658.76	12.30	57,300
3	866.49	12.30	10,700
4	631.37	12.30	7,800
5	301.61	12.30	3,700
6	217.24	12.30	2,700
7	216.44	12.30	2,700
8	113.27	12.30	1,400
Total	10,690.24		109,000

Summary

Total average annual without project damages are summarized in the table below.

Average annual damages without project

Category	Amount
Urban	$6,525,100
Rural	739,100
Agricultural	(91,600)
Other agricultural	(76,300)
Residential and nonresidential	(571,200)
Transportation	109,000
Total	7,373,200

PROJECT BENEFITS

The proposed raise of Lake Darling Dam and operational features would reduce the frequency of damaging flows along the Souris River. The benefits are the difference between average annual flood damages without the project (see the previous section) and average annual damages with the project. Therefore, average annual damages with the project were determined for the urban, rural, and transportation damage categories. An added benefit is future capital cost savings. The following sections present the development of benefits for the project.

URBAN

With project damages were computed in the same manner as without project damages. HEC2 water surface profiles for modified conditions were used. The following table shows average annual damages with project. Future growth to residential contents is not included.

Average annual damages with project, urban areas (1)

	Average annual damages		
Urban area	Residential	Nonresidential (2)	Total
Johnson's Addition	$30,200		$30,200
Brook's Addition	12,200		12,200
Talbot's Nursery	5,400		5,400
King's Court	18,100		18,100
Robinswood Estates and Country Club Acres	40,100		40,100
Tierrecita Vallejo	4,700		4,700
Minot	492,200	$1,134,300	1,626,500
Highway 2 through Logan	7,700	3,100	10,800
Sawyer	7,400		7,400
Velva	32,600	41,500	74,100
Total	650,600	1,178,900	1,829,500

(1) 1982 development conditions.
(2) Commercial, industrial, and public.

Future growth in residential contents damages with project was determined in the same manner as future growth under without project conditions. The following table shows urban residential damages including future growth. No growth in average annual damages was projected for other damage categories.

Average annual with project urban residential damage, including future growth

Urban area	Category	Year 1982	1985	2000	2035	Increase 1985-2035	Average annual equivalent factor	Average annual equivalent of increase	Total average annual damages
Johnson's Addition	Structure	$18,100	$18,100	$18,100	$18,100				
	Contents	12,100	12,100	18,200	36,300				
	Total	30,200	30,200	36,300	54,400	24,200	0.3243	$7,800	$38,000
Brook's Addition	Structure	7,300	7,300	7,300	7,300				
	Contents	4,900	4,900	10,900	14,700				
	Total	12,200	12,200	18,200	22,000	9,700	0.3243	3,100	15,300
Talbot's Nursery	Structure	3,200	3,200	3,200	3,200				
	Contents	2,200	2,200	3,300	6,500				
	Total	5,400	5,400	6,500	9,700	4,300	0.3243	1,400	6,800
King's Court	Structure	10,900	10,900	10,900	10,900				
	Contents	7,200	7,200	10,800	21,700				
	Total	18,100	18,100	21,700	32,600	14,500	0.3243	4,700	22,800
Robinswood Estates and Country Club Acres	Structure	24,100	24,100	24,100	24,100				
	Contents	16,000	16,000	24,000	48,200				
	Total	40,100	40,100	48,100	72,300	32,200	0.3243	10,400	50,500
Tierrecita Vallejo	Structure	2,800	2,800	2,800	2,800				
	Contents	1,900	1,900	2,900	5,600				
	Total	4,700	4,700	5,700	8,400	3,700	0.3243	1,200	5,900
Minot	Structure	295,300	295,300	295,300	295,300				
	Contents	196,900	196,900	295,300	590,600				
	Total	492,200	492,200	590,600	885,900	393,700	0.3243	127,700	619,900
Highway 2 through Logan	Structure	4,600	4,600	4,600	4,600				
	Contents	3,100	3,100	4,600	9,200				
	Total	7,700	7,700	9,200	13,800	6,100	0.3243	2,000	9,700
Sawyer	Structure	4,400	4,400	4,400	4,400				
	Contents	3,000	3,000	4,500	8,900				
	Total	7,400	7,400	8,900	13,300	5,900	0.3243	1,900	9,300
Velva	Structure	19,600	19,600	19,600	19,600				
	Contents	13,000	13,000	19,600	39,100				
	Total	32,600	32,600	39,200	58,700	26,100	0.3243	8,500	41,100
Total		650,600	650,600	784,400	1,171,100	520,500		168,700	819,300

The sum of average annual damages for residential including future growth and for nonresidential is the average annual urban damages with project (see the following table).

Total with project average annual urban damages (including future growth)

Urban area	Average annual damages Residential	Nonresidential	Total
Johnson's Addition	$38,000		$38,000
Brook's Addition	15,300		15,300
Talbot's Nursery	6,800		6,800
King's Court	22,800		22,800
Robinswood Estates and Country Club Acres	50,500		50,500
Tierrecita Vallejo	5,900		5,900
Minot	619,900	$1,134,300	1,754,200
Highway 2 through Logan	9,700	3,100	12,800
Sawyer	9,300		9,300
Velva	41,100	41,500	82,600
Total	819,300	1,178,900	1,998,200

RURAL

With project damages were computed in the same manner as without project damages. Again, the categories of agricultural, other agricultural, and residential and nonresidential damages were used.

Agricultural

With the project, the frequency of flooding of agricultural lands would be reduced. The dam would lower flood peaks but would also tend to increase the duration of lower flows. Extending the duration could lead to later planting on the acres flooded. Consequently, the damage per acre flooded would increase with the dam in place even though the average annual acres flooded would decrease.

The Vicksburg crop damage program was used to determine the with project damage per acre figure. With project HEC2 water surface

profiles were used to determine average annual acres flooded with project. No future growth was assumed. The following table presents with project average annual agricultural damages.

Average annual damages with project, agricultural

Evaluation area	Land use Type	Percent	Damage per acre	Average annual acres flooded	Average annual damages
1	1	67	$6.42	724	$4,649
	2	33	10.46	362	3,787
		100		1,086	8,436
2		100	13,67	2,614	35,740
3	1	50	38.33	258	9,910
	2	50	6.36	259	1,644
		100		517	11,554
4		100	20.97	358	7,515
5	1	50	32.03	58	1,849
	2	50	15.42	57	890
		100		115	2,739
6		100	9.36	91	848
7	1	50	12.25	59	723
	2	50	4.62	59	273
		100		118	996
8	1	67	3.60	33	120
	2	33	8.23	17	137
		100		50	257
Total					68,085

Other Agricultural

With project damages were computed using the DDS program and with project HEC2 water surface profiles. This information was input to the EAD program to determine average annual damages. These damages are shown in the table below. No future growth was assumed.

Average annual with project damages, other agricultural

Evaluation Area	Amount
1	$4,294
2	2,717
3	8,229
4	4,049
5	3,974
6	3,944
7	4,297
8	643
Total	32,147

Residential and Nonresidential Structures

With project damages were determined from with project HEC2 water surface profiles and the DDS program. The EAD program was used to compute average annual damages.

Average annual with project damages,
rural residential and nonresidential

Evaluation area	Average annual damages		
	Residential	Nonresidential	Total
1	$11,427		$11,427
2	38,231		38,231
3	16,584		16,584
4	26,826		26,826
5	26,952		26,952
6	32,904	$98,713	131,617
7	29,791	29,790	59,581
8	1,067		1,067
Total	183,782	128,503	312,285

Future growth in the value of residential contents was determined using the same method as for without project conditions. The following table shows rural residential damages including future growth.

Average annual with project damages, rural residential (includes future growth)

Evaluation area	Category	Year 1982	1985	2000	2035	Increase 1985-2035	Average annual equivalent factor	Average annual equivalent of increase	Total average annual damages
1	Structure	$6,856	$6,856	$6,856	$6,856				
	Contents	4,571	4,571	6,857	13,713				
	Total	11,427	11,427	13,713	20,569	$9,142	0.3243	$2,965	$14,392
2	Structure	22,939	22,939	22,939	22,939				
	Contents	15,292	15,292	22,938	45,876				
	Total	38,231	38,231	45,877	68,815	30,584	0.3243	9,918	48,149
3	Structure	9,950	9,950	9,950	9,950				
	Contents	6,634	6,634	9,951	19,902				
	Total	16,584	16,584	19,901	29,852	13,268	0.3243	4,303	20,887
4	Structure	16,096	16,096	16,096	16,096				
	Contents	10,730	10,730	16,095	32,190				
	Total	26,826	26,826	32,191	48,286	21,460	0.3243	6,959	33,785
5	Structure	16,171	16,171	16,171	16,171				
	Contents	10,781	10,781	16,172	32,343				
	Total	26,952	26,952	32,343	48,514	21,562	0.3243	6,993	33,945
6	Structure	19,742	19,742	19,742	19,742				
	Contents	13,162	13,162	19,743	39,486				
	Total	32,904	32,904	39,485	59,228	26,324	013243	8,537	41,441
7	Structure	17,875	17,875	17,875	17,875				
	Contents	11,916	11,916	17,874	35,748				
	Total	29,791	29,791	35,749	53,623	23,832	0.3243	7,729	37,520
8	Structure	640	640	640	640				
	Contents	427	427	641	1281				
	Total	1,067	1,067	1,281	1,921	854	0.3243	277	1,344
Total		183,782	183,782	220,540	330,808	147,026		47,681	231,463

Adding residential damages with future growth to nonresidential damages gives total rural residential and noresidential damages (see the following table).

With project average annual residential and nonresidential damages (including future growth)

Evaluation area	Average annual damages		
	Residential	Nonresidential	Total
1	$14,392		$14,392
2	48,149		48,149
3	20,887		20,887
4	33,785		33,785
5	33,945		33,945
6	41,441	$98,713	140,154
7	37,520	29,790	67,310
8	1,344		1,344
Total	231,463	128,503	359,966

Summary

Total rural with project damages are presented in the following table.

Total average annual with project rural damages (including future growth)

Evaluation area	Average annual damages			
	Agricultural	Other agricultural	Residential and nonresidential	Total
1	$8,436	$4,294	$14,392	$27,122
2	35,740	2,717	48,149	86,606
3	11,554	8,229	20,887	40,670
4	7,515	4,049	33,785	45,349
5	2,739	3,974	33,945	40,658
6	848	3,944	140,154	144,946
7	996	4,297	67,310	72,603
8	257	643	1,344	2,244
Total	68,085	32,147	359,966	460,198

TRANSPORTATION

Transportation damages with project would decrease because fewer acres would be flooded on an average annual basis. The following table presents average annual transportation damages with the project. No future growth was assumed.

Average annual with project transportation damages

Evaluation area	Acres flooded	Damage per acre	Damages
1	1,086.12	$12.30	$13,400
2	2,614.40	12.30	32,200
3	517.09	12.30	6,400
4	358.36	12.30	4,400
5	115.46	12.30	1,400
6	90.63	12.30	1,100
7	118.01	12.30	1,500
8	50.03	12.30	600
Total	4,950.43		61,000

FUTURE CAPITAL COST SAVINGS

In the next 10 to 30 years, nine dams and four bridges will have to be replaced as their useful life will have expired. Replacing them as part of the project would eliminate the need for future replacement. Consequently, a benefit can be credited to the project for the early replacement of these facilities. The following table summarizes the future capital cost savings for dam and bridge replacement.

Future capital cost savings

Replaced facility	Replacement cost	Project life (years)	Remaining life (years)	Interest and amortization of replacement cost (1)	Present worth of 1 per period over additional life	Present worth of 1 from end of remaining life	Interest and amortization factor for 100 years at 5 1/8 percent	Annual benefit
Lake Darling Dam	$21,300,000	80	30	$1,099,100	17.91	0.2233	0.0516	$226,800
Dam 41	870,000	60	10	44,900	17.91	0.6067	0.0516	25,200
Dam 87	610,000	70	20	31,500	17.91	0.3680	0.0516	10,700
Dam 96	610,000	60	10	31,500	17.91	0.6067	0.0516	17,700
Dam 320	670,000	70	20	34,600	17.91	0.3680	0.0516	11,800
Dam 326	550,000	70	20	28,400	17.91	0.3680	0.0516	9,700
Dam 332	550,000	70	20	28,400	17.91	0.3680	0.0516	9,700
Dam 341	550,000	70	20	28,400	17.91	0.3680	0.0516	9,700
Dam 357	670,000	70	20	34,600	17.91	0.3680	0.0516	11,800
Highway 5	400,000	50	30	20,600	12.33	0.2233	0.0516	2,900
Highway 28	380,000	50	10	19,600	16.87	0.6067	0.0516	10.300
Grano Crossing	380,000	50	30	19,600	12.33	0.2233	0.0516	2,800
Soo Line Railroad	1,580,000	100	20	81,500	19.15	0.6067	0.0516	29,600
Total								378,700

(1) Interest and amortization at 5 1/8 percent for 100 years = 0.0516.
(2) Additional life equals project life minus remaining life.

TOTAL BENEFITS

Benefits for the project are the difference between damages without the project and damages with the project plus the benefit of future capital cost savings. The table below gives the project benefits.

Average annual project benefits (1)

Benefit category	Average annual damages		Average annual benefits
	Without project	With project	
Flood damage reduction			
Urban	$6,525,100	$1,998,200	$4,526,900
Rural			
Agricultural	91,600	68,100	23,500
Other Agricultural	76,300	32,100	44,200
Residential and nonresidential	571,200	360,000	211,200
Transportation	109,000	61,000	48,000
Total	7,373,200	2,519,400	4,853,800
Future capital cost savings			378,700
Total			5,232,500

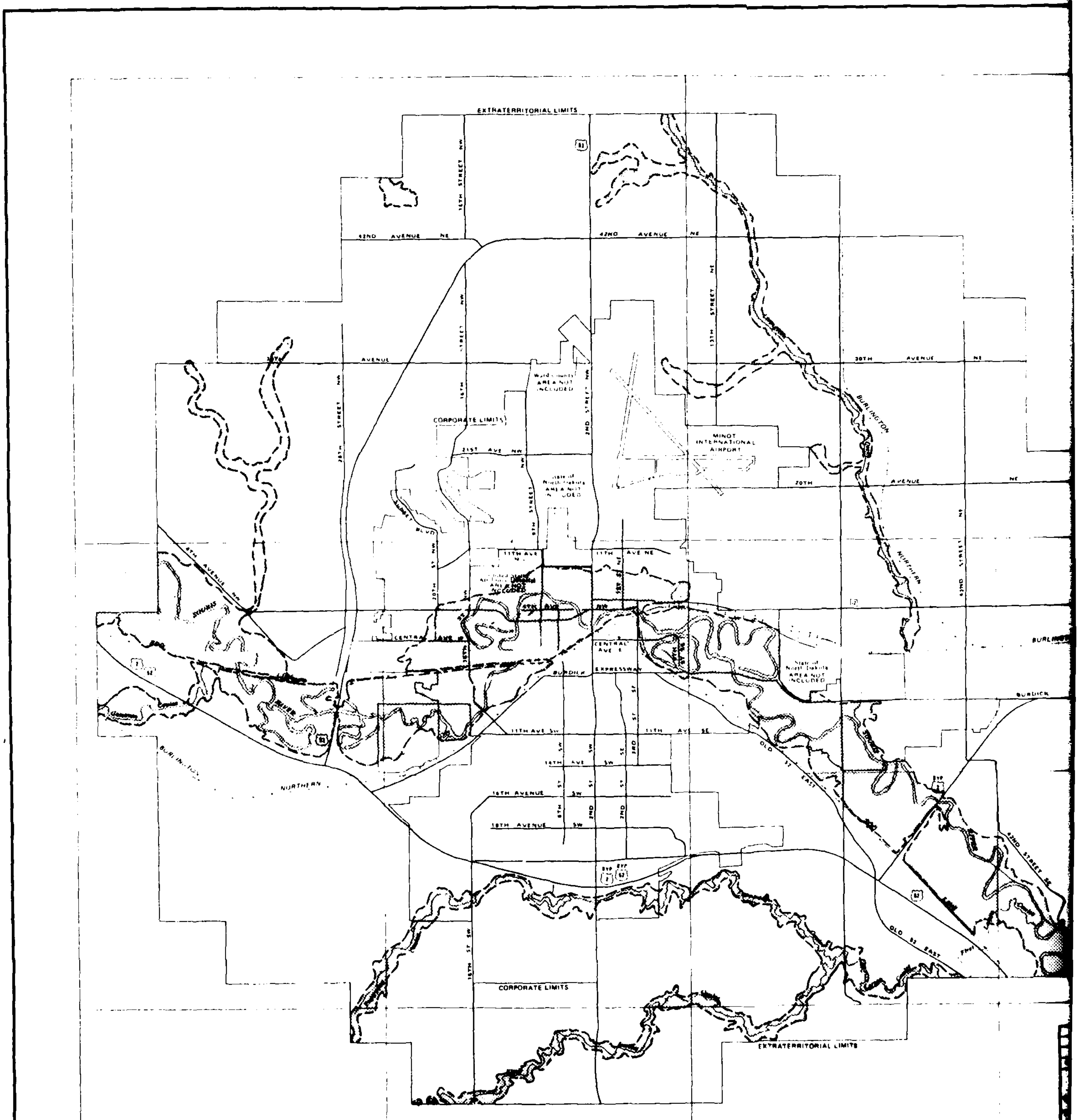
(1) 1982 development conditions, October 1982 price levels

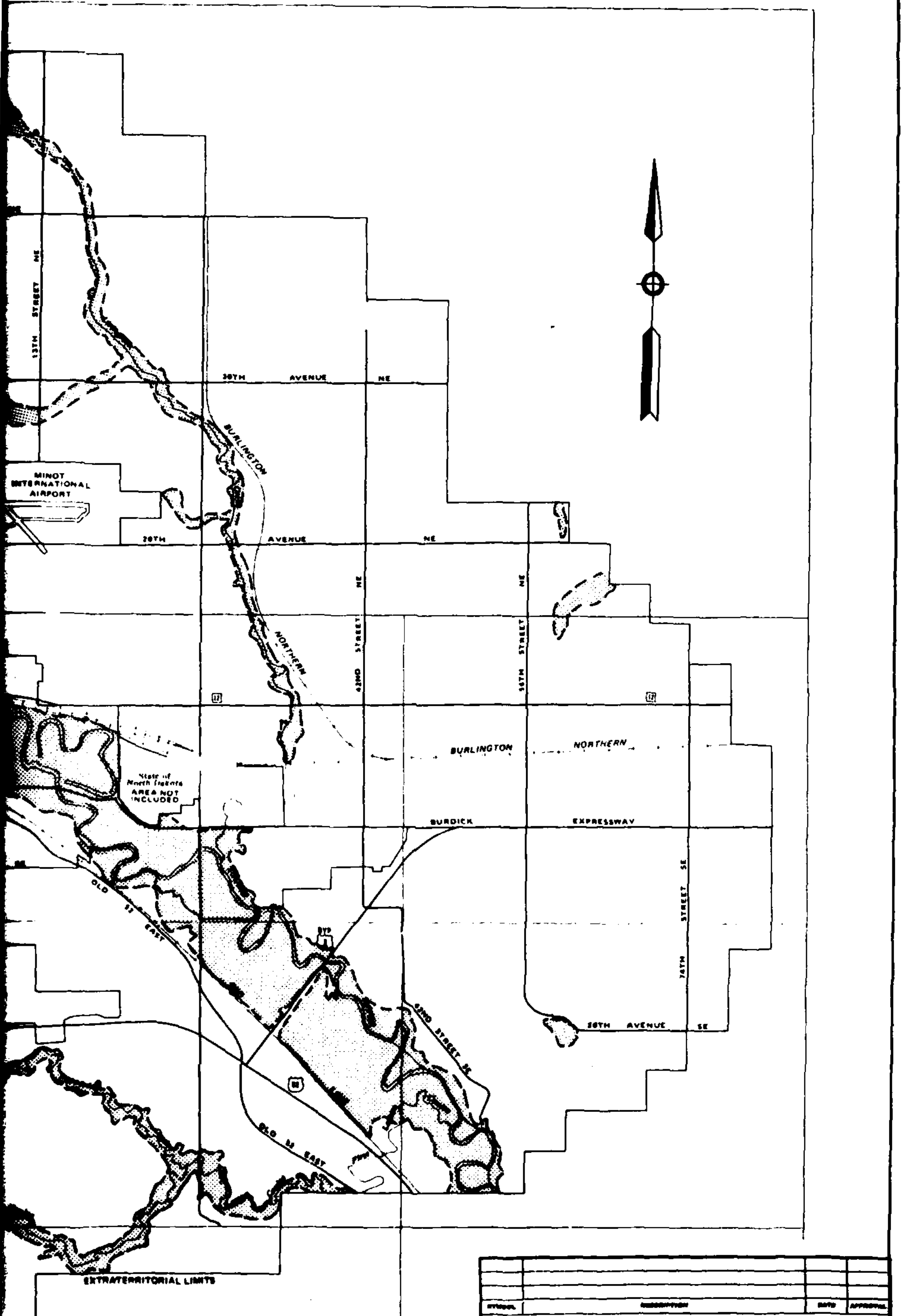
BENEFIT-COST RATIO

To allow comparison with project average annual costs, average annual benefits were updated to October 1983 price levels. The index factors used are those used to prepare the fiscal year 1985 budget testimony for Congress. The following table summarizes benefits and costs of the project.

Comparison of average annual benefits and costs

Item	Amount: October 1982 prices	Index	October 1983 prices
Average annual benefits			
Flood damage reduction	$4,526,900	1.043	$4,721,600
Urban			
Rural			
Agricultural	23,500	1.082	25,400
Other agricultural	44,200	1.005	44,400
Residential and nonresidential	211,200	1.043	220,300
Transportation	48,000	1.050	50,400
Future capital cost savings	378,700	1.050	397,600
Total	5,232,500		5,459,700
Average annual costs			4,183,200
Benefit-cost ratio			1.31


EXTRATERRITORIAL LIMITS
16TH STREET NW
42ND AVENUE NE
13TH STREET NE
30TH AVENUE NE
Ward County AREA NOT INCLUDED
CORPORATE LIMITS
2ND STREET NW
MINOT INTERNATIONAL AIRPORT
21ST AVE NW
20TH AVENUE NE
State of North Dakota AREA NOT INCLUDED
BURLINGTON NORTHERN
11TH AVE NE
42ND STREET NE
CENTRAL AVE
CENTRAL AVE E
BURDICK EXPRESSWAY
State of North Dakota AREA NOT INCLUDED
BURDICK
11TH AVE SW
11TH AVE SE
OLD 83 EAST
16TH AVENUE SW
18TH AVENUE SW
BURLINGTON NORTHERN
42ND STREET SE
OLD 83 EAST
CORPORATE LIMITS
EXTRATERRITORIAL LIMITS



DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGN MEMORANDUM NO. 3 GENERAL

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
100 YEAR FLOODED AREA

MINOT NORTH DAKOTA
(EXISTING CONDITIONS)

L.A.R. D.J.P.
J.M.A.
A.M.K.

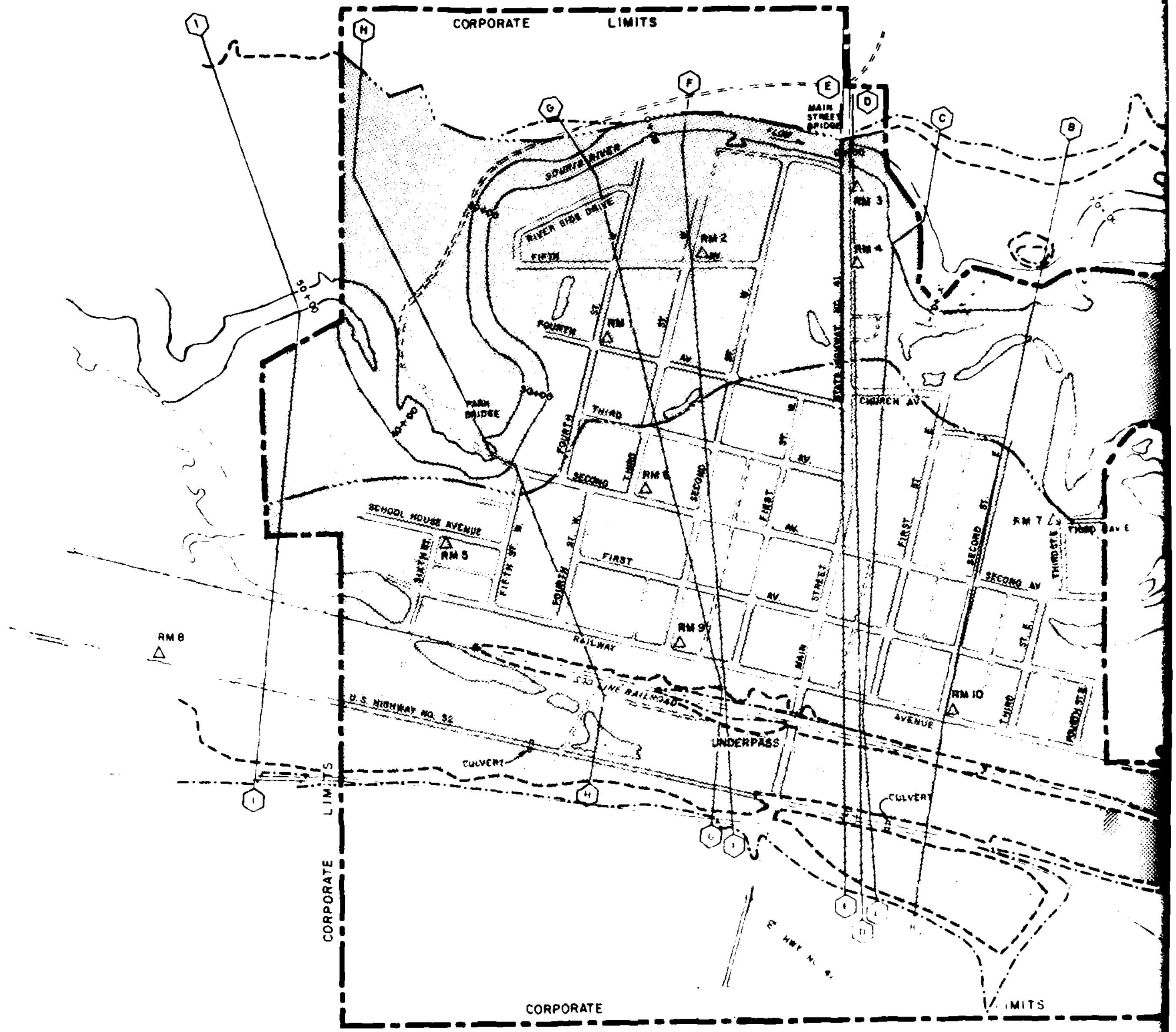
DATE: JUNE 1983

DRAWING NUMBER RI-R-5/680

SHEET OF

PLATE 6-1

1 2



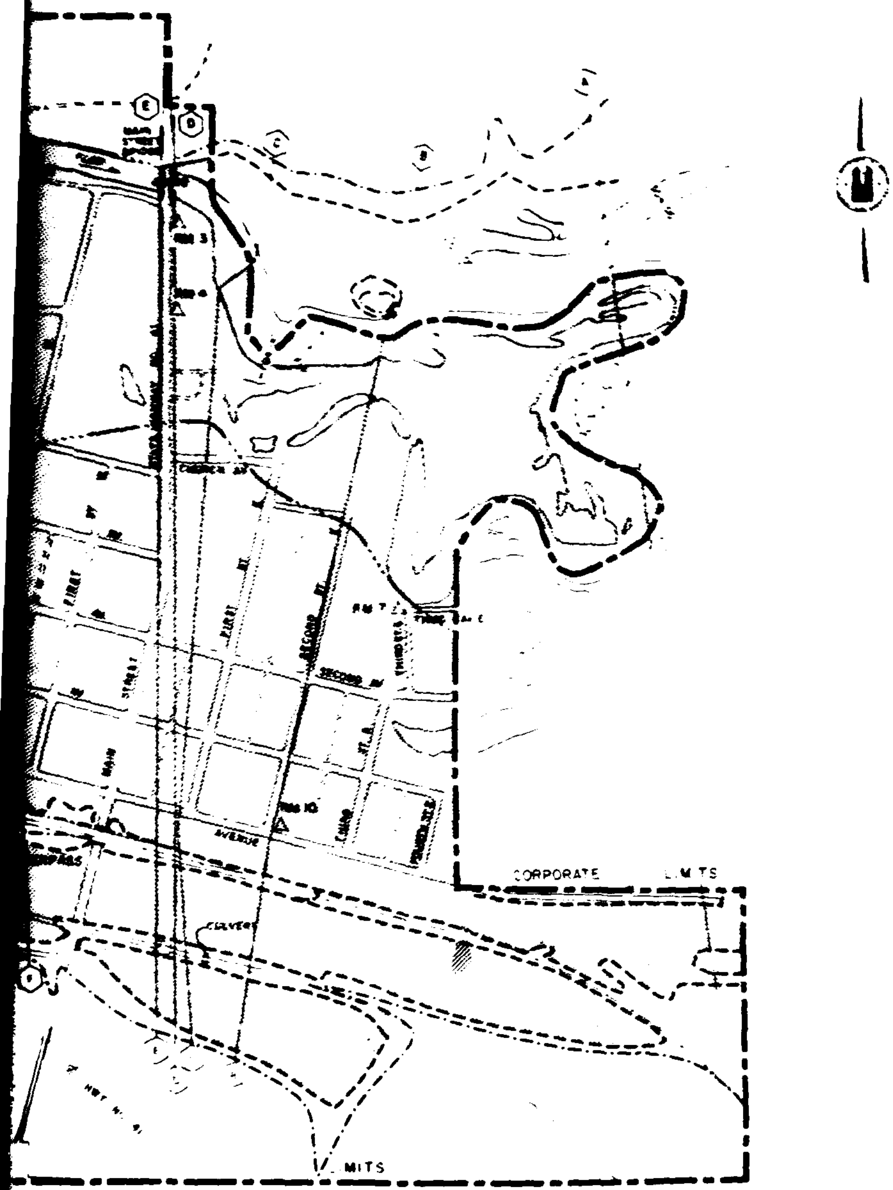
LEGEND

FLOODWAY BOUNDARY
100 YR. FLOOD BDRY.
500 YR. FLOOD BDRY.
CROSS SECTION
10+00 STATIONING
CORPORATE LIMITS

NOTE: STATION 0+00 AT CENTER OF STATE HIGHWAY 41 BRIDGE

APPROX. SCALE IN FEET

400 0 400 800



0+00 AT CENTER OF
HIGHWAY 41 BRIDGE
SCALE IN FEET
400 800

DEPARTMENT OF THE ARMY

DESIGN MEMORANDUM NO 3 GENERAL

L.A.R. B.J.P.

J.M.J.

A.M.K.

FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
100YEAR FLOODED AREA
VELVA NORTH DAKOTA
(EXISTING CONDITIONS)

DATE: JUNE 1983

5/881

PLATE C-2


LEGEND
FENCE
BUILDING
FIELD LINE
NOTE
Mark Hurd

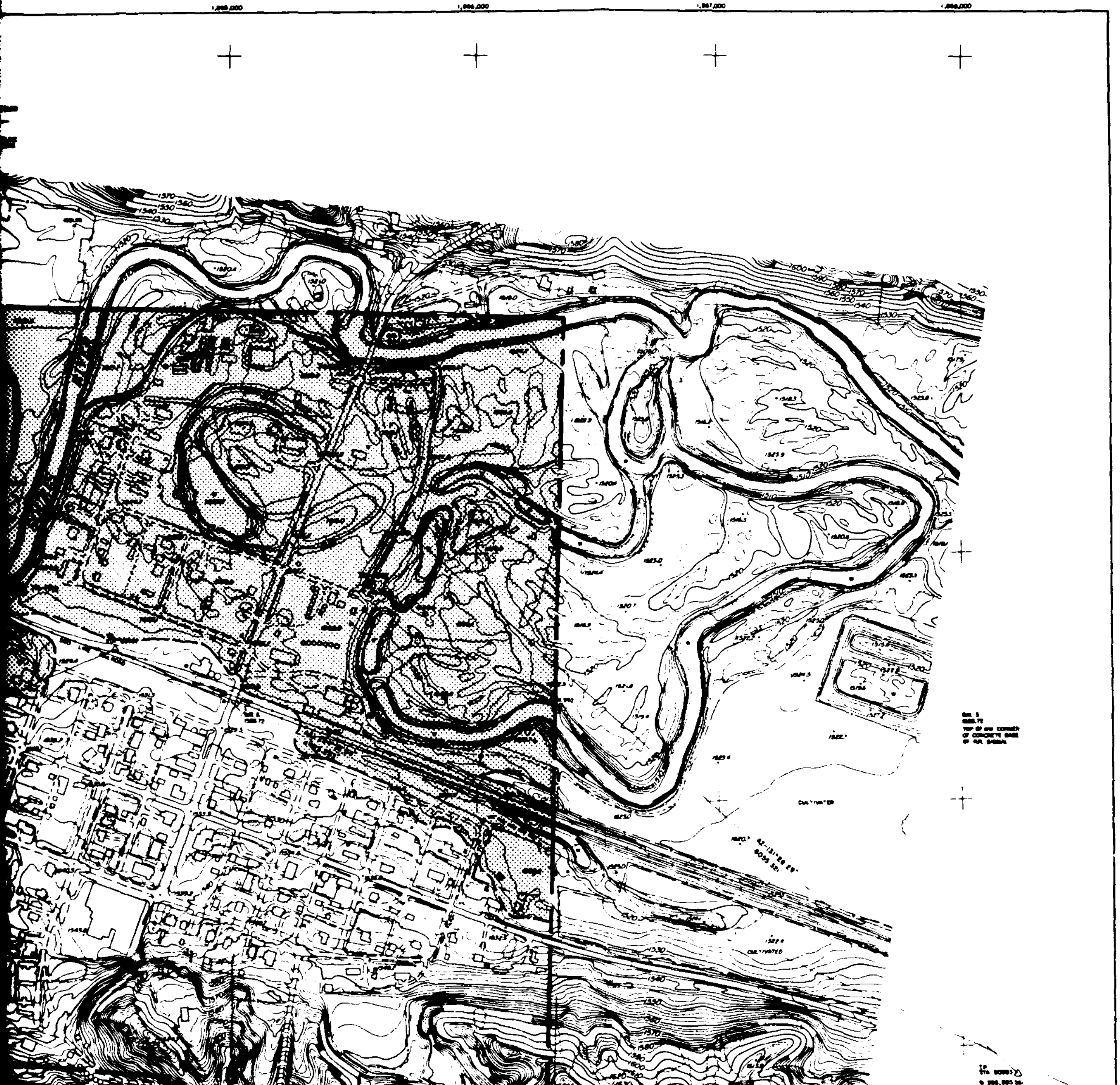

DEPARTMENT OF THE ARMY
DESIGN MEMORANDUM NO. 3 GENERAL
FLOOD CONTROL - LAKE DARLING
SOURIS RIVER, NORTH DAKOTA
100 YEAR FLOODED AREA
SAWYER N.D.
(EXISTING CONDITIONS)
JUNE 1983
RI-R-5/682
CULTIVATED

PLATE C-3

FLOOD CONTROL
LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

DESIGN MEMORANDUM NO. 3
GENERAL PROJECT DESIGN

APPENDIX D

DETAILED COST ESTIMATES

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
Federal Costs					
01	Lands and Damages				
	Payment for 1220 acres in easement	Job	Sum		234,500
	Acquisition cost	Job	Sum		77,500
	Land management cost	Job	Sum		2,000
	Subtotal, Lands and Damages				314,000
02	Relocations				
02.1	Roads				
	State Highway #5				
	Care of traffic				
	Random fill	C.Y.	22,350	3.00	67,050
	Gravel surface	C.Y.	1,240	20.00	24,800
	Embankment				
	Stripping	C.Y.	4,200	2.50	10,500
	Common excavation	C.Y.	10,920	2.50	27,300
	Channel excavation	C.Y.	88,680	2.00	177,360
	Random fill	C.Y.	16,610	1.50	24,915
	Riprap	C.Y.	14,360	22.00	315,920
	Bedding	C.Y.	7,180	15.00	107,700
	Roadway				
	Subbase course	C.Y.	2,330	12.00	27,960
	Base course	C.Y.	2,330	12.00	27,960
	2" Bituminous base	S.Y.	11,190	4.00	44,760
	2" Bituminous wear course	S.Y.	11,190	4.00	44,760
	Guard rails	L.F.	8,860	16.00	141,760
	Bridge				
	Concrete (bridge pier raise)	C.Y.	16	200.00	3,200
	Re-steel	LB	1,230	0.50	615
	Concrete (new structure)	C.Y.	340	200.00	68,000
	Re-steel	Lb	27,500	0.50	13,750
	Raise & reset superstructure	Job	Sum	***	35,000
	Remove exist. abutment conc.	C.Y.	90	50.00	4,500
	Remove exist. abutment piles	Each	36	150.00	5,400
	W 36 x 50 beams (50' lg)	Each	8	1,600.00	12,800
	Bearings	Each	12	200.00	2,400
	Contingencies				142,590
	Subtotal, State Highway #5				1,331,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
02.1	Roads				
	State Highway #28				
	Embankment				
	Pervious fill	C.Y.	58,760	3.00	176,280
	Random fill	C.Y.	58,760	1.50	88,140
	Riprap 21"	C.Y.	11,590	22.00	254,980
	Riprap 12"	C.Y.	8,810	22.00	193,820
	Bedding	C.Y.	11,590	15.00	173,850
	Stripping	C.Y.	4,020	2.50	10,050
	Roadway				
	6" Subbase	C.Y.	2,760	12.00	33,120
	6" Base	C.Y.	2,560	12.00	30,720
	3" Bituminous	S.Y.	13,870	4.75	65,883
	Guard rails	L.F.	7,800	18.00	140,400
	Bridge				
	Concrete	C.Y.	30	200.00	6,000
	Re-steel	Lb	6,800	0.50	3,400
	Structured steel	Lb	28,000	0.65	18,200
	Steel encased conc. piles 13 3/4" Ø	L.F.	1,900	45.00	85,500
	Steel sheet piling	S.F.	4,000	16.00	64,000
	Pre-stressed conc. box girder 59" - 11" x 27" x 36"	Each	39	5,000.00	195,000
	Remove exist. bridge	Job	Sum	***	60,000
	Contingencies				191,657
	Subtotal, State Highway #28				1,791,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
02.1	Roads				
	Grano Crossing				
	Embankment				
	Stripping	C.Y.	17,680	2.50	44,200
	Random fill	C.Y.	89,000	1.50	133,500
	Riprap	C.Y.	38,580	22.00	848,760
	Bedding	C.Y.	22,050	15.00	330,750
	Roadway				
	6" Subbase	C.Y.	3,300	12.00	39,600
	6" Base	C.Y.	3,650	12.00	43,800
	3" Bituminous	S.Y.	15,600	4.75	74,100
	Guard rail	L.F.	12,700	18.00	228,600
	Bridge (to be raised)				
	Concrete	C.Y.	50	200.00	10,000
	Re-steel	Lb	4,000	0.50	2,000
	Raise & re-set superstructure	Job	Sum	***	35,000
	Contingencies				214,690
	Subtotal, Grano Crossing				2,005,000
	Renville Co. Road 9				
	Riprap	C.Y.	2,300	22.00	50,600
	Gravel bedding	C.Y.	1,150	15.00	17,250
	4" stabilized aggregate base	C.Y.	1,300	12.00	15,600
	Contingencies				10,550
	Subtotal, Renville Co. Road 9				94,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
02.1	Roads (cont'd)				
	Lake Darling Dam Crossing-				
	Approach roads				
	Right abutment				
	Random fill	C.Y.	65,000	3.50	227,500
	Stripping	C.Y.	3,830	2.50	9,575
	Topsoil	C.Y.	2,640	4.00	10,560
	Seeding	Acre	5	1000.00	5,000
	Stabilized aggregate				
	6" subbase	C.Y.	1,920	12.00	23,040
	6" base	C.Y.	1,920	12.00	23,040
	3½ " bit. pavement (24' road)	S.F.	82,800	0.65	53,820
	Left abutment				
	Random fill	C.Y.	28,850	3.50	100,975
	Stripping	C.Y.	1,240	2.50	3,100
	Topsoil	C.Y.	830	4.00	3,320
	Seeding	Acre	1.5	1000.00	1,500
	Stabilized aggregate				
	6" subbase	C.Y.	400	12.00	4,800
	6" base	C.Y.	400	12.00	4,800
	3" bit. pavement (24'road)	S.F.	17,280	0.65	11,232
	Embankment road				
	Stabilized aggregate				
	6" subbase	C.Y.	2,440	12.00	29,280
	6" base	C.Y.	2,440	12.00	29,280
	3½" bit. pavement (24' road)	S.F.	79,200	0.65	51,480
	Guardrail	L.F.	10,400	20.00	208,000
	Spillway bridge				
	Prestressed concrete				
	Beams 46 ft. long	Each	25	200.00	5,000
	Structural concrete	C.Y.	200	200.00	40,000
	Reinf. steel	Lbs.	36,000	0.60	21,600
	Bridge railing	L.F.	530	35.00	18,550
	Contingencies				114,548
	Subtotal, Lake Darling Dam Crossing				1,000,000
	Subtotal, Road Relocations				6,221,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
02.2	Railroads				
	Soo Line Railroad				
	Temporary track				
	Random fill	C.Y.	6,940	4.50	31,230
	Pervious fill	C.Y.	9,500	7.00	66,500
	Riprap	C.Y.	810	22.00	17,820
	Bedding	C.Y.	320	16.00	5,120
	Ballast	C.Y.	180	25.00	4,500
	Rail (100 lb)	L.F.	800	26.00	20,800
	Ties 7" x 8" x 8.5'	Each	246	18.00	4,428
	Tie plates	Each	500	6.00	3,000
	Rail spikes	Each	2,000	2.00	4,000
	Embankment				
	Stripping	C.Y.	5,100	3.00	15,300
	Common excavation	C.Y.	4,500	3.25	14,625
	Channel	C.Y.	284,200	2.00	568,400
	Random fill	C.Y.	98,870	2.20	217,514
	Pervious fill	C.Y.	100,000	7.00	700,000
	Riprap	C.Y.	21,640	22.00	476,080
	Reclaimed riprap	C.Y.	10,000	6.00	60,000
	Bedding	C.Y.	16,100	16.00	257,600
	Care of water	Job	Sum	***	125,000
	Remove existing bridge	Job	Sum	***	60,000
	Track				
	Sub-ballast	C.Y.	9,500	25.00	237,500
	Tob-ballast	C.Y.	4,300	25.00	107,500
	Rail (100 lb)	L.F.	20,950	26.00	544,700
	Ties 7" x 9" x 8.5'	Each	6,415	14.00	89,810
	Tie plates	Each	12,800	6.00	76,800
	Spikes	Each	51,300	2.00	102,600
	Bridge				
	Reinf. concrete piles (1' Ø)	L.F.	13,040	30.00	391,200
	Reinf. concrete	C.Y.	1,930	250.00	482,500
	Struct. steel	Lb.	328,000	0.65	213,200
	Contingencies				587,273
	Subtotal, Soo Line Railroad				5,485,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
02.3	Cemeteries, Utilities, and Structures				
	Power Lines				
	Montana-Dakota Utilities Co.				
	Remove 0.7 mi. wood pole transmission line and replace with higher poles. Abandon 2.1 mi, distribution cable in Mouse River Park area and provide 2.8 miles of new underground distribution cable	Job	Sum		69,000
	Telephone Lines				
	Souris River Telephone Mutual Aid Corporation				
	Abandon 3.8 mi of underground cable, construct 4.5 mi of underground cable, and reinforce 1.9 miles of underground cable with water-proof cable	Job	Sum		57,000
	Water Supply				
	Renville County Water System Floodproof or modify well sites	Job	Sum		25,000
Subtotal	Relocations - Cemeteries, Utilities and Structures				151,000
Total Relocations					11,857,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06	Fish and Wildlife Facilities				
06.1	Lake Darling Dam				
	Dam Embankment				
	Site preparation				
	Cofferdam fill	C.Y.	19,110	6.00	114,660
	Dewatering	Job	Sum	800,000.00	800,000
	Removal of existing intake to Pond "A" (in dry)				
	Reinf. concrete	C.Y.	3,030	25.00	75,750
	12' x 10' roller gates	Each	2	5,000.00	10,000
	12' x 12' trash rack & misc.	Each	2	1,000.00	2,000
	Removed and returned excavation	C.Y.	3,500	2.50	8,750
	Spillway removal				
	Reinf. concrete	C.Y.	1,500	250.00	375,000
	Embankment section				
	Rockfill	Tons	39,090	13.00	508,170
	Sand drain	C.Y.	55,300	15.00	829,500
	Berm fill (from excav)	C.Y.	355,000	1.00	355,000
	Impervious fill	C.Y.	227,900	5.00	1,139,500
	Riprap, 18"	Tons	18,750	15.00	281,250
	Riprap, 15"	Tons	11,655	15.00	174,825
	Bedding, 9"	C.Y.	6,230	15.00	93,450
	Bedding, 6"	C.Y.	3,110	15.00	46,660
	Topsoil	C.Y.	8,400	4.00	33,600
	Stripping	C.Y.	39,960	2.50	99,900
	18" per. drain pipe	L.F.	3,400	20.00	68,000
	Seeding	Acre	17.0	1,000.00	17,000
	Plastic filter cloth	S.Y.	1,630	8.00	13,040
	Filter control (const)	C.Y.	2,730	15.00	40,950
	Instrumentation	Job	Sum	20,000.00	20,000
	Erosion control (const)	Job	Sum	15,000.00	15,000
	Spillway				
	Common Excavation	C.Y.	656,320	2.50	1,640,800
	Rock excavation	C.Y.	90,510	15.00	1,357,650
	Backfill	C.Y.	25,460	3.50	89,110
	Riprap, 24"	Tons	7,665	15.00	114,975
	Riprap, 12"	Tons	25,470	15.00	382,050
	Bedding, 12"	C.Y.	3,220	15.00	48,300
	Bedding, 6"	C.Y.	7,290	15.00	109,350

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.1	Lake Darling Dam (cont'd)				
	Spillway (cont'd)				
	Drainage & frost protection	Job	Sum	20,000.00	20,000
	Control structure				
	Ogee concrete	C.Y.	2,480	200.00	496,000
	Pier conc.	C.Y.	5,311	200.00	1,062,200
	Reinf. steel	Lbs.	310,760	0.60	186,456
	Tainter gates (43'W x 22'H)	Each	5	200,000.00	1,000,000
	Chute				
	Slab conc.	C.Y.	6,920	100.00	692,000
	Sidewalls conc.	C.Y.	1,200	200.00	240,000
	Reinf. steel	Lbs.	557,700	0.60	334,620
	Stilling basin				
	Slab conc.	C.Y.	4,950	100.00	495,000
	Sidewall conc.	C.Y.	1,600	200.00	320,000
	Endsill & baffle bl. conc.	C.Y.	180	200.00	36,000
	Reinf. steel	Lbs.	428,500	0.60	257,100
	Wing walls				
	W.w. conc.	C.Y.	1,260	200.00	252,000
	Reinf. steel	Lbs.	48,200	0.60	28,920
	Soil anchors	L.F.	1,370	50.00	68,500
	Low flow outlet				
	Service gates	Each	8	4,000.00	32,000
	Trash racks	Each	4	1,200.00	4,800
	Plunge pool				
	Slab conc.	C.Y.	6,900	100.00	690,000
	Reinf. steel	Lbs.	55,800	0.60	33,480
	Channel levee				
	Random fill	C.Y.	40,420	3.50	141,470
	Stripping	C.Y.	18,270	2.50	45,675
	Topsoil	C.Y.	430	4.00	1,720
	Seeding	Acre	0.8	1,000.00	800
	Contingencies				1,797,013
	Total, Lake Darling Dam				17,100,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.2	Upper Souris Refuge (Operational Features)				
	Dam No. 41				
	Embankment				
	Stripping	C.Y.	1,500	2.50	3,750
	Excavation	C.Y.	15,200	3.00	45,600
	Riprap	C.Y.	2,900	22.00	63,800
	Bedding	C.Y.	1,200	15.00	18,000
	Stab. aggregate	C.Y.	4,900	12.00	58,800
	Subbase	C.Y.	4,900	12.00	58,800
	Spillway				
	Excavation, structure & outlet channel	C.Y.	9,000	2.50	22,500
	Stripping	C.Y.	2,500	2.50	6,250
	Backfill (compacted)	C.Y.	3,200	3.50	11,200
	Riprap	C.Y.	3,400	32.00	74,800
	Bedding	C.Y.	1,400	15.00	21,000
	Reinf. concrete	C.Y.	2,000	200.00	400,000
	Stoplogs	S.F.	20	12.00	240
	Remove clean paint, reinstall 10' x 12' slide gate	Job	Sum	***	4,500
	Power co. cost for service	Job	Sum	***	11,000
	Power gate hoist	Job	Sum	***	31,000
	Electrical construction	Job	Sum	***	74,000
	Contingencies				108,760
	Subtotal, Dam #41				1,014,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.2	Upper Souris Refuge (Operation Features) cont'd				
	Service Roads in Reservoir				
	Embankment, borrow	C.Y.	55,000	3.25	178,750
	Riprap	C.Y.	16,000	22.00	352,000
	Bedding	C.Y.	8,000	16.00	128,000
	Stab. aggregate	C.Y.	4,900	12.00	58,800
	Seeding	Acre	9	1,000.00	9,000
	36" CMP	L.F.	360	65.00	23,400
	Contingencies				90,050
	Subtotal, Service Roads in Reservoir				840,000
	Outlet from Lake Darling to Pond A				
	Intake structure	Job	Sum	***	20,000
	Gated control structure	Job	Sum	***	55,000
	42" RCP	L.F.	1,500	95.00	142,500
	Reinf. concrete cradle and seepage cellars	C.Y.	100	200.00	20,000
	Excavation	C.Y.	7,300	2.00	14,600
	Backfill	C.Y.	6,400	1.80	11,520
	Manholes w/cleanouts	Each	2	2,200.00	4,400
	Impact energy dissapator	Job	Sum	***	16,500
	Plug for existing channel	C.Y.	1,850	3.00	5,550
	Contingencies				34,930
	Subtotal, Water Supply to Pond A				325,000
	Replacement Facility for Spillway Fishing Area				
	Fishing Area	Job	Sum	65,000.00	65,000
	Subtotal, Fishing Area				65,000
	Raise Boat Launch Facilities				
	Raise boat launch facilities	Sites	3	15,000.00	45,000
	Subtotal, Boat Launches				45,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.2	Upper Souris Refuge (Operation Features) cont'd				
	Modify Fencing				
	Fencing	L.F.	5,000	12.00	60,000
	Contingencies				7,000
	Subtotal, Modify Fencing				67,000
06.2	Heaters, Actuators, Repair Gates at Dam 87				
	Remove & replace deteriated concrete	C.Y.	50	450.00	22,500
	Remove & reinstall radial gate	Each	1	2,000.00	2,000
	Replace deteriated gate parts	Job	Sum	***	2,200
	Replace seal gates & trunion pins	Job	Sum	***	6,700
	Furnish & install motorized hoist	Job	Sum	***	3,700
	Furnish & install heating system	Job	Sum	***	9,200
	Clean & paint slide gate	Job	Sum	***	300
	Furnish & install motorized gate hoist	Each	1	6,700.00	6,700
	Electrical construction	Job	Sum	***	74,000
	Contingencies				15,700
	Subtotal, Dam #87 Heaters, Actuators, Gate Repairs				143,000
	Same Cost at Dam #96				143,000
	Therefore, Subtotal Heaters, Actuators, Gate Repairs at Dams 87 & 96				286,000
	Low Flow Outlet from Pond A				
	Remove concrete spillway	Job	Sum	***	6,250
	Construct embankment	C.Y.	240	5.00	1,200
	30" RCP	L.F.	50	65.00	3,250
	Concrete	C.Y.	5	350.00	1,750
	30" Ø control gate	Each	1	3,500.00	3,500
	Contingencies				2,050
	Subtotal, Low Flow Outlet from Pond A				18,000
	Subtotal, Upper Souris Refuge Operational Features				2,660,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.3	Upper Souris Refuge (Mitigation Features)				
	Low Flow Outlet @ Pond A				
	Concrete Removal	Job	Sum	***	500
	Excavation	C.Y.	20	2.50	50
	Backfill	C.Y.	20	3.50	70
	Concrete	C.Y.	5	200.00	1,000
	30" RCP	L.F.	50	65.00	3,250
	30" slide gate	Each	1	3,500.00	3,500
	Contingencies				1,030
	Subtotal, Low Flow Outlet				9,400
	Upgrade Dam #96				
	Gated structure				
	Riprap	C.Y.	100	22.00	2,200
	Bedding	C.Y.	50	15.00	750
	Dewatering	Job	Sum	***	58,000
	Concrete removal	C.Y.	340	50.00	17,000
	New concrete	C.Y.	250	200.00	50,000
	New radial gate, hoist & heater	Each	2	28,000.00	56,000
	New slide gate & hoist	Each	1	16,000.00	16,000
	Backfill	C.Y.	300	3.50	1,050
	Excavation	C.Y.	300	2.50	750
	Contingencies				24,250
	Subtotal, Gated Structure				226,000
	Spillway				
	Riprap	C.Y.	400	22.00	8,800
	Bedding	C.Y.	130	15.00	1,950
	Excavation	C.Y.	2,700	2.50	6,750
	Backfill	C.Y.	2,700	3.50	9,450
	Concrete removal	C.Y.	1,100	50.00	55,000
	Concrete	C.Y.	980	200.00	196,000
	Contingencies				33,050
	Subtotal, Spillway				311,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.3	Upper Souris Refuge Mitigation Features (cont'd)				
	Embankment				
	Riprap	C.Y.	3,695	22.00	81,290
	Bedding	C.Y.	1,470	15.00	22,050
	Stabilized aggregate	C.Y.	140	12.00	1,680
	Embankment repair	Job	Sum	***	10,000
	Contingencies				13,980
	Subtotal, Embankment				129,000
	Subtotal, Dam 96 Upgrading				666,000
	Upgrade Gated Structure at Dam 87				
	Riprap	C.Y.	100	22.00	2,200
	Bedding	C.Y.	50	15.00	750
	Dewatering	Job	Sum	***	58,000
	Concrete removal	C.Y.	340	50.00	17,000
	New Concrete	C.Y.	250	200.00	50,000
	New radial gate, hoist heater	Each	2	28,000.00	56,000
	New slide gate & hoi	Each	1	16,000.00	16,000
	Backfill	C.Y.	300	3.50	1,050
	Excavation	C.Y.	300	2.50	750
	Contingencies				24,250
	Subtotal, Dam 87 Gated Structure				226,000
06.3	Bypass at Dam 87				
	48" Ø RCP	L.F.	400	95.00	38,000
	Excavation	C.Y.	6,500	2.50	16,250
	Backfill	C.Y.	6,500	3.50	22,750
	Concrete	C.Y.	10	200.00	2,000
	Contingencies				9,000
	Subtotal, Bypass at Dam 87				88,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.3	Upper Souris Refuge Mitigation Features (cont'd)				
	Raise Spillway at Dam 87, Rehab. Embankment & Rehab. Marsh				
	Spillway				
	Riprap	C.Y.	400	22.00	8,800
	Bedding	C.Y.	130	15.00	1,950
	Excavation	C.Y.	2,700	2.50	6,750
	Backfill	C.Y.	2,700	3.50	9,450
	Concrete removal	C.Y.	1,100	50.00	55,000
	Concrete	C.Y.	980	200.00	196,000
	Contingencies				33,050
	Subtotal, Spillway				311,000
	Embankment				
	Riprap	C.Y.	11,280	22.00	248,160
	Bedding	C.Y.	3,766	15.00	56,490
	Stripping	C.Y.	4,338	2.50	10,845
	Stabilized aggregate	C.Y.	533	12.00	6,396
	Contingencies				39,109
	Subtotal, Embankment				361,000
	Rehab Marsh	Job	Sum		50,000
	Subtotal, Raise Spillway, Rehab. Embankment & Marsh				722,000
06.3					
	Upgrade Dikes A, B, & C				
	Embankment borrow	C.Y.	20,000	3.25	65,000
	Stabilized aggregate	C.Y.	1,480	12.00	17,760
	Riprap	C.Y.	6,500	22.00	143,000
	Bedding	C.Y.	2,600	15.00	39,000
	Seeding	Acre	17	1,000.00	17,000
	Contingencies				34,240
	Subtotal Dikes A, B, & C				316,000

AD-A136 228 LAKE DARLING FLOOD CONTROL PROJECT SOURIS RIVER NORTH DAKOTA GENERAL PROJECT DESIGN(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT JUN 83

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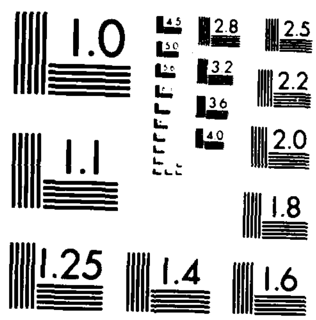
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DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.3	Upper Souris Refuge Mitigation Features (cont'd)				
	Upgrade Downstream Trails				
	Random fill	C.Y.	40,000	1.50	60,000
	Stabilized aggregate	C.Y.	3,000	12.00	36,000
	Seeding	Acres	2	1,000.00	2,000
	36" Ø CMP	L.F.	200	50.00	10,000
	Contingencies				12,000
	Subtotal, Upgrade Downstream Trails				120,000
	Subtotal, Upper Souris Refuge (Mitigation Features)				2,147,400
06.4	J. Clark Salyer Refuge (Operational Features)				
	Carp Control Structure				
	Electric fish barrier	Job	Sum	***	80,000
	Embankment Borrow	C.Y.	72,000	3.25	234,000
	Seeding	Acre	9	1,000.00	9,000
	Riprap	C.Y.	370	22.00	8,140
	Bedding	C.Y.	185	15.00	2,775
	Concrete	C.Y.	670	200.00	134,000
	Excavation	C.Y.	1,400	2.50	3,500
	Contingencies				56,585
	Subtotal, Carp Control Structure				528,000
	Heaters, Actuators and Repaired Gates				
	Dam #320				
	Remove gates	Job	Sum	***	1,500
	Transport gates to shop & return	Job	Sum	***	3,000
	Clean, repair and paint gates	Job	Sum	***	17,000
	Remove & replace seal plates and trunnion pins	Job	Sum	***	21,000
	Reinstall gates	Job	Sum	***	1,200
	Replace gate hoists & wire rope	Job	Sum	***	14,000
	Install heating system	Job	Sum	***	15,000
	Electrical service	Job	Sum	***	56,000
	Contingencies				15,300
	Subtotal Dam #320				144,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.4	J. Clark Salyer Operation Features (cont'd)				
	Dam #326				
	Remove gates	Job	Sum	***	1,500
	Transport gates to shop & return	Job	Sum	***	3,000
	Clean, repair and paint gates	Job	Sum	***	14,000
	Remove & replace seal plates and trunnion pins	Job	Sum	***	18,000
	Reinstall gates	Job	Sum	***	900
	Replace gate hoists & wire rope	Job	Sum	***	9,500
	Install heating system	Job	Sum	***	15,000
	Electrical service	Job	Sum	***	156,000
	Contingencies				26,100
	Subtotal, Dam #326				244,000
	Dam #332				
	Remove gates	Job	Sum	***	1,500
	Transport gates to shop & return	Job	Sum	***	3,000
	Clean, repair & paint gates	Job	Sum	***	22,000
	Remove & replace seal plates and trunnion pins	Job	Sum	***	20,000
	Reinstall gates	Job	Sum	***	1,000
	Replace gate hoists & wire rope	Job	Sum	***	13,000
	Install heating system	Job	Sum	***	15,000
	Electrical service	Job	Sum	***	87,000
	Contingencies				19,500
	Subtotal, Dam #332				182,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.4	J. Clark Salyer Operation Features (cont'd)				
	Dam #341				
	Remove gates	Job	Sum	***	1,500
	Transport gates to shop & return	Job	Sum	***	3,000
	Clean, repair and paint gates	Job	Sum	***	17,000
	Remove & replace seal plates and trunnion pins	Job	Sum	***	20,000
	Reinstall gates	Job	Sum	***	1,000
	Replace gate hoists & wire rope	Job	Sum	***	13,000
	Install heating system	Job	Sum	***	15,000
	Electrical Service	Job	Sum	***	81,000
	Contingencies				18,500
	Subtotal, Dam #341				170,000
	Dam #357				
	Remove gates	Job	Sum	***	1,500
	Transport gates to shop & return	Job	Sum	***	---
	Clean, repair and paint gates	Job	Sum	***	7,700
	Remove & replace seal plates and trunnion pins	Job	Sum	***	21,000
	Reinstall gates	Job	Sum	***	1,200
	Replace gate hoists & wire rope	Job	Sum	***	14,000
	Install heating system	Job	Sum	***	15,000
	Electrical service	Job	Sum	***	89,000
	Contingencies				17,600
	Subtotal, Dam #357				167,000
	Subtotal Heaters, Actuators, & Repaired Gates				907,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.4	J. Clark Salyer Operation Features (cont'd)				
	Raise Service Roads Trails & Launches				
	Fill (from site excavation)	C.Y.	70,500	1.50	105,750
	Seeding	Acre	3	1,000.00	3,000
	Stab. aggregate	C.Y.	8,800	12.00	105,600
	36" CMP	L.F.	360	65.00	23,400
	Contingencies				28,250
	Subtotal, Roads				266,000
	Subtotal, J. Clark Salyer Refuge (Operational Features)				1,701,000
06.5	J. Clark Salyer Refuge (Mitigation Features)				
	Construct Potholes				
	Excavation	C.Y.	57,680	2.00	115,360
	Contingencies				13,640
	Subtotal, Potholes				129,000
	Upgrade Dam #320				
	Gated structure				
	Riprap	C.Y.	100	22.00	2,200
	Bedding	C.Y.	50	15.00	750
	Dewatering	Job	Sum	***	60,000
	Concrete removal	C.Y.	200	25.00	5,000
	Gates	Each	2	40,000.00	80,000
	Excavation	C.Y.	800	2.50	2,000
	Backfill	C.Y.	800	3.50	2,800
	Concrete	C.Y.	148	200.00	29,600
	Contingencies				19,650
	Subtotal, Dam #320 Gated Structure				202,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.5	J. Clark Salyer Refuge (Mitigation Features)				
	Spillway				
	Riprap	C.Y.	400	22.00	8,800
	Bedding	C.Y.	130	15.00	1,950
	Excavation	C.Y.	4,200	2.50	10,500
	Backfill	C.Y.	4,200	3.50	14,700
	Concrete removal	C.Y.	1,100	25.00	27,500
	Concrete	C.Y.	1,400	200.00	280,000
	Contingencies				41,550
	Subtotal, Spillway				385,000
	Embankments				
	Stripping	C.Y.	50,000	2.50	125,000
	Embankment (borrow)	C.Y.	327,000	3.50	1,144,500
	Stab. aggregate	C.Y.	4,500	12.00	54,000
	Seeding	Acre	55	1,000.00	55,000
	Contingencies				165,500
	Subtotal, Embankment				1,544,000
	Subtotal, Upgrade Dam #320				2,131,000
	Upgrade Dam # 326				
	Gated structure				
	Same as 320 Gated structure				202,000
	Subtotal, Dam #326				202,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.5	J. Clark Salyer Mitigation Features (cont'd)				
	Spillway				
	Riprap	C.Y.	400	22.00	8,800
	Bedding	C.Y.	130	15.00	1,950
	Excavation	C.Y.	2,700	2.50	6,750
	Backfill	C.Y.	2,700	3.50	9,450
	Concrete removal	C.Y.	1,100	25.00	27,500
	Concrete	C.Y.	980	200.00	196,000
	Contingencies				30,550
	Subtotal, Spillway				281,000
	Embankment				
	Stripping	C.Y.	23,000	2.50	57,500
	Embankment (borrow)	C.Y.	90,700	3.50	317,450
	Stab. aggregate	C.Y.	2,400	12.00	28,800
	Seeding	Acre	24	1,000.00	24,000
	Contingencies				51,250
	Subtotal, Embankment				479,000
	Subtotal, Upgrade Dam #326				962,000
	Upgrade Dam #332				
	Gated structure				
	Same as Dam #320 Gated structure				202,000
	Subtotal, Gated structure #332				202,000
	Spillway				
	Same as Spillway #326				281,000
	Subtotal, Spillway #332				281,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.5	J. Clark Salyer Mitigation Features (cont'd)				
	Embankment				
	Stripping	C.Y.	12,500	2.50	31,250
	Embankment (borrow)	C.Y.	61,000	3.50	213,500
	Stab. aggregate	C.Y.	1,300	12.00	15,600
	Seeding	Acre	14	1,000.00	14,000
	Contingencies				32,650
	Subtotal, Embankment #332				307,000
	Subtotal, Upgrade Dam #332				790,000
	Upgrade Dam #341				
	Same as Dam #320, Gated Structure				202,000
	Subtotal, Gated Structure #332				202,000
	Spillway #341				
	Same as Spillway #326				281,000
	Subtotal, Spillway #341				281,000
	Embankment				
	Stripping	C.Y.	7,600	2.50	19,000
	Embankment (borrow)	C.Y.	32,200	3.50	112,700
	Stab. aggregate	C.Y.	800	12.00	9,600
	Seeding	Acre	9	1,000.00	9,000
	Contingencies				17,700
	Subtotal, Embankment #341				168,000
	Subtotal, Upgrade Dam #341				651,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
06.5	J. Clark Salyer Mitigation Features (cont'd)				
	Upgrade Dam #357				
	Gated Structure Dam #320				202,000
	Subtotal, Gated Structure #357				202,000
	Spillway				
	Same as Spillway #320				385,000
	Subtotal, Spillway #357				385,000
	Embankment				
	Stripping	C.Y.	6,600	2.50	16,500
	Embankment (borrow)	C.Y.	24,400	3.50	85,400
	Stab. aggregate	C.Y.	760	12.00	9,120
	Seeding	Acres	8	1,000.00	8,000
	Contingencies				13,980
	Total Embankment				133,000
	Subtotal, Upgrade Dam #357				720,000
	Low Flow Structure @ Dam #320				
	Excavation	C.Y.	150	2.50	375
	Backfill	C.Y.	150	3.50	525
	Concrete	C.Y.	20	200.00	4,000
	48" Ø RCP	L.F.	130	95.00	12,350
	Slide gate	Each	1	5,000.00	5,000
	Riprap	C.Y.	12	22.00	264
	Bedding	C.Y.	6	15.00	90
	Contingencies				2,396
	Subtotal, Low Flow @ Dam #320				25,000
	Low Flow Structure @ Dam #326 (as above)				25,000
	Subtotal, J. Clark Salyer Refuge Mitigation Features				5,433,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
09	Channels				
	Canadian compensatory costs	Job	Sum		774,000
	Hydrometeorological Instrumentation	Job	Sum		150,000
	Total Channels				
11	Levees				
	Renville County Park				
	Channel Excavation	L.F.	2,100	95.00	199,500
	Embankments	L.F.	5,150	75.00	386,250
	Culverts	L.F.	110	250.00	27,500
	Pumping Plant & Inlet Structure	Each	1	328,200.00	328,200
	Contingencies				118,550
	Subtotal, Renville County Park				1,060,000
	McKinney Cemetery				
	Channel Excavation	L.F.	200	78.00	15,600
	Embankments	L.F.	1,035	70.00	72,450
	Culverts	L.F.	110	55.00	6,050
	Ditches	L.F.	1,035	1.00	1,035
	Portable pump	Each	1	5,000.00	5,000
	Contingencies				11,865
	Subtotal, McKinney Cementery				112,000
	Eckert Ranch				
	Channel excavation	L.F.	600	115.00	69,000
	Embankments	L.F.	1,000	80.00	80,000
	Catch basin	Each	1	500.00	500
	36" Culverts	L.F.	270	48.00	12,960
	Pond Excavation	Job	Sum	***	8,000
	Portable pump	Each	1	5,000.00	5,000
	Contingencies				24,540
	Subtotal, Eckert Ranch				200,000
	Total Levees				1,372,000

DETAILED COST ESTIMATES

LAKE DARLING DAM UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
19	Buildings, Grounds and Utilities	Job	Sum		12,000
20	Gassman Coulee Warning System				
	Gassman Coulee Flood Warning System	Job	Sum		221,000
	Contingencies				29,000
	Subtotal, Gassman Coulee Warning System				250,000
	Subtotal, Lake Darling Dam Unit				
30	Engineering and Design				3,350,000
31	Supervision and Administration				
	Supervision and Inspection				(1,951,000)
	Overhead				(928,000)
	Subtotal, Supervision and Administration				2,879,600
	TOTAL, LAKE DARLING DAM UNIT (All Federal Costs)				50,000,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

Johnson's Addition

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
Federal Costs					
09	Channels				
	Temporary diversion	Job	Sum		1,600
	Channel excavation	L.F.	300	23.50	7,050
	Contingencies				1,350
	Subtotal, Channels				10,000
11	Levees				
	Embankment	L.F.	4,500	31.00	139,500
	Contingencies				16,500
	Subtotal, Embankments				156,000
	Interior Drainage Facilities				
	Fill areas	AC	2.4	12,000.00	28,800
	Culverts	L.F.	135	38.50	5,198
	Ditches	L.F.	1,320	27.00	35,640
	Gravity	Job	Sum		33,000
	Contingencies				12,362
	Subtotal, Interior Drainage Facilities				115,000
	Subtotal, Levees				271,000
13	Pumping Plants (including contingencies)	EA	1	160,000.00	160,000
30	Engineering and Design				54,000
31	Supervision and Administration				
	Supervision & Inspection				20,000
	Overhead				8,000
	Subtotal, Supervision & Administration				28,000
	Total Federal Costs, (Johnson's Addition)				523,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

Johnson's Addition

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
	Non-Federal Costs				
01	Lands and Damages				
	Payments				220,000
	Acquisition cost				30,000
	Subtotal, Lands and Damages				250,000
02	Relocations				
	Structures	Job	Sum		325
	Gas Lines	Job	Sum		2,400
	Water Lines	Job	Sum		2,400
	Contingencies				*875*
	Subtotal, Relocations				6,000
	Total Non-Federal Costs (Johnson's Addition)				256,000
	Total Federal & Non-Federal Costs				779,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

Brook's Addition

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
	Federal Costs				
09	Channels				
	Temporary diversion	Job	Sum		8,400
	Channel excavation	L.F.	1,350	78.50	106,000
	Contingencies				13,600
	Subtotal, Channels				128,000
11	Levees				
	Embankments	L.F.	4,785	65.00	311,025
	Contingencies				37,975
	Subtotal, Embankments				349,000
	Interior Drainage Facilities				
	Fill areas	AC	1.3	15,000.00	19,500
	Culverts	L.F.	270	20.00	5,400
	Ditches	L.F.	1,780	18.00	32,040
	Gravity outlet	EA	1	38,000.00	25,500
	Contingencies				10,560
	Subtotal, Interior Drainage Facilities				93,000
	Subtotal, Levees				442,000
13	Pumping Plants (Including contingencies)	EA	1	160,000.00	160,000
30	Engineering and Design				92,000
31	Supervision and Administration				
	Supervision & inspection				34,000
	Overhead				14,000
	Subtotal, Supervision & Administration				48,000
	Total Federal Costs, (Brook's Addition)				870,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

Brook's Addition

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
	Non-Federal Costs				
01	Land and Damages				
	Payments (26.5 Acres)				150,000
	Acquisition cost				40,000
	Subtotal, Lands and Damages				190,000
02	Relocations				
	Structures	Job	Sum		2,000
	Gas line	Job	Sum		900
	Raise garage	Job	Sum		1,700
	Contingencies				1,400
	Subtotal, Relocations				6,000
	Total Non-Federal Costs (Brook's Addition)				196,000
	Total Federal and Non-Federal Costs				1,066,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

Talbott's Nursery

Cost Acct. No.	Item	Unit	Quantity	Unit Cost	Amount
				$	$
	Federal Costs				
11	Levees				
	Embankments	L.F.	2,650	11.00	29,150
	Contingencies				3,850
	Subtotal, Embankments				33,000
	Interior Drainage Facilities				
	Culverts	L.F.	550	35.50	19,525
	Ditches	L.F.	565	8.00	4,520
	Gravity outlet	Each	1	26,000.00	26,000
	Contingencies				5,955
	Subtotal, Interior Drainage Facilities				56,000
	Subtotal, Levees				89,000
13	Pumping Plants (including contingencies)	Each	1	149,000.00	149,000
30	Engineering and Design				31,000
31	Supervision and Administration				
	Supervision & inspection				11,500
	Overhead				4,500
	Subtotal, Supervision & Administration				16,000
	Total Federal Cost, (Talbott's Nursery)				285,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

Talbott's Nursery

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
Non-Federal Costs					
01	Land and Damages				
	Payments				280,000
	Acquisition cost				20,000
	Subtotal, Lands and Damages				300,000
02	Relocations				
	Septic system-alternate	Job	Sum		11,000
	Contingencies				2,000
	Subtotal, Relocations				13,000
	Total Non-Federal Costs (Talbott's Nursery)				313,000
	Total Federal & Non-Federal Cost				598,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

Country Club Acres and Robinwood Estates

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
Federal Costs					
09	Channels				
	Temporary Diversion	Job	Sum		6,700
	Channel Excavation	L.F.	780	105.00	81,900
	Contingencies				11,400
	Subtotal, Channels				100,000
11	Levees				
	Embankments	L.F.	7,180	47.00	337,460
	Contingencies				40,540
	Subtotal, Embankments				378,000
	Interior Drainage Facilities				
	Fill areas	AC	1.8	12,000.00	21,600
	Culverts	L.F.	1,320	44.00	58,080
	Ditches	L.F.	1,840	20.00	36,800
	Gravity outlet	Each	1	27,000.00	27,000
	Contingencies				17,520
	Subtotal, Interior Drainage Facilities				161,000
	Subtotal, Levees				539,000
13	Pumping Plants (including contingencies)	Each	1	163,000.00	163,000
30	Engineering and Design				101,000
31	Supervision and Administration				
	Supervision & inspection				38,000
	Overhead				16,000
	Subtotal, Supervision & Administration				54,000
	Total Federal Cost, (Country Club Acres and Robinwood Estates)				957,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

Country Club Acres & Robinwood Estates

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
Non-Federal Costs					
01	Lands and Damages				
	Payments				170,000
	Acquisition cost				60,000
Subtotal, Lands and Damages					230,000
02	Relocations				
	Structures	Job	Sum		350
	Septic systems	Job	Sum		1,800
	Gas lines	Job	Sum		5,800
	Underground power lines	Job	Sum		4,600
	Water lines				5,800
	Contingencies				2,650
Subtotal, Relocations					21,000
Total Non-Federal Costs (Country Club Acres & Robinwood Estates)					251,000
Total Federal & Non-Federal Costs					1,208,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

King's Court and Rostad's Addition

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
	Federal Costs				
07	Channels				
	Temporary diversion	Job	Sum	81.00	3,400
	Channel excavation	L.F.	1,210		98,000
	Contingencies				12,600
	Subtotal, Channels				114,000
11	Levees				
	Embankments	L.F.	4,030	44.00	179,335
	Contingencies				21,665
	Subtotal, Embankments				201,000
	Interior Drainage Facilities				
	Fill areas	AC	1.1	15,000.00	16,500
	Culverts	L.F.	240	16.00	3,840
	Ditches	L.F.	670	10.00	6,700
	Storm Sewers	Job	Sum		118,000
	Gravity outlet	Each	1	34,000.00	34,000
	Contingencies				21,960
	Subtotal, Interior Drainage Facilities				201,000
	Subtotal, Levees				402,000
13	Pumping Plants (including contingencies)	Each	1	153,000	153,000
30	Engineering and Design				83,000
31	Supervision and Administration				
	Supervision & Inspection				31,000
	Overhead				13,000
	Subtotal, Supervision & Administration				44,000
	Total Federal Costs (King's Court and Rostad's Addition)				796,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

King's Court and Rostad's Addition

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
Non-Federal Costs					
01	Land and Damages				
	Payments				90,000
	Acquisition cost				60,000
	Subtotal, Lands and Damages				150,000
02	Relocations				
	Structures	Job	Sum		350
	Gas lines	Job	Sum		7,700
	Water lines	Job	Sum		7,700
	Contingencies				2,250
	Subtotal, Relocations				18,000
	Total Non-Federal Costs (King's Court and Rostad's Addition)				168,000
	Total Federal & Non-Federal Costs				964,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

Tierrecita Vallejo

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
	Federal Costs				
09	Channels				
	Temporary diversion	Job	Sum		3,400
	Channel excavation	L.F.	690	30.00	20,700
	Contingencies				3,900
	Subtotal, Channels				28,000
11	Levees				
	Embankments	L.F.	5,115	16.00	81,000
	Contingencies				10,160
	Subtotal, Embankments				92,000
	Interior Drainage Facilities				
	Fill areas	AC	0.3	27,000.00	8,100
	Culverts	L.F.	235	17.00	3,995
	Ditches	L.F.	200	10.00	2,000
	Gravity Outlet No. 1	Each	1	41,000.000	41,000
	Gravity Outlet No. 2	Each	1	21,000.00	21,000
	Contingencies				9,905
	Subtotal, Interior Drainage Facilities				86,000
	Subtotal, Levees				178,000
13	Pumping Plants (including contingencies)	Each	1	176,000.00	176,000
30	Engineering and Design				46,000
31	Supervision & Administration				
	Supervision & inspection				17,000
	Overhead				7,000
	Subtotal, Supervision & Administration				24,000
	Total, Federal Costs (Tierrecita Vallejo)				452,000

DETAILED COST ESTIMATES

BURLINGTON TO MINOT LEVEES UNIT

Tierrecita Vallejo

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
	Non-Federal Costs (Tierrecita Vallejo)				
01	Lands and Damages				
	Payments				100,000
	Acquisition cost				40,000
	Total Non-Federal Costs (Tierrecita Vallejo)				140,000
	Total Federal & Non-Federal Costs				592,000
	Summary- Burlington to Minot Levee Unit				
	Total Federal Costs				3,883,000
	Total Non-Federal Costs				1,324,000
	TOTAL				5,207,000

DETAILED COST ESTIMATES

SAWYER LEVEES UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
Federal Costs					
11	Levees				
	Embankments	L.F.	4,225	50.00	211,250
	Contingencies				25,750
	Subtotal, Embankments				237,000
	Interior Drainage Facilities				
	Fill areas	AC	0.25	12,000.00	3,000
	Culverts	L.F.	45	38.00	1,710
	Ditches	L.F.	1,000	17.00	17,000
	Gravity outlet	Each	1	36,000.00	36,000
	Contingencies				7,290
	Subtotal, Interior Drainage Facilities				65,000
	Subtotal, Levees				302,000
30	Engineering and Design				36,000
31	Supervision and Administration				
	Supervision & inspection				14,000
	Overhead				6,000
	Subtotal, Supervision & Administration				20,000
	Total Federal Costs (Sawyer)				358,000

DETAILED COST ESTIMATES

SAWYERS LEVEES UNIT (*Cont'd*)

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
Non-Federal Costs					
01 Lands and Damages					
	Payments				90,000
	Acquisition cost				40,000
Subtotal, Lands and Damages					130,000
02 Relocations					
	Structures	Job	Sum		4,600
	Road raise	Job	Sum		5,300
	Contingencies				1,100
Subtotal, Relocations					11,000
Total Non-Federal Costs (Sawyer)					141,000
Total Federal & Non-Federal Costs					499,000

VELVA LEVEES UNIT

(Detailed estimate provided in Velva Feature Design Memorandum Dated November 1982)

Total Federal Cost	4,830,000
Total Non-Federal Cost	336,000
TOTAL	5,166,000

DETAILED COST ESTIMATES

RURAL IMPROVEMENTS UNIT

Cost Acct. No.	Item	Unit	Quantity	Unit Cost $	Amount $
	Federal Costs				
12	Relocations				
	Raised Residences	Each	23	14,000.00	322,000
	Levees	Each	50	16,000.00	800,000
	Access Roads	Mi	23.8	115,000.00	2,737,000
	Contingencies				461,000
	Subtotal, Relocations				4,320,000
30	Engineering and Design				300,000
31	Supervision and Administration				
	Inspection				194,000
	Overhead				94,000
	Subtotal, Supervision and Administration				288,000
	Total Federal Costs (Rural Improvements)				4,908,000
	Non-Federal Costs				
11	Lands and Damages				
	Payments				2,250,000
	Acquisition costs				102,000
	Subtotal, Lands and Damages				2,352,000
	Total Non-Federal Costs (Rural Improvements)				2,352,000
	Total Federal & Non-Federal Costs				7,260,000
	Total Federal Costs - Lake Darling Project				63,979,000
	Total Non-Federal Costs - Lake Darling Project				4,153,000
	Total Federal & Non-Federal Costs - Lake Darling Project				68,132,000

FLOOD CONTROL
LAKE DARLING
SOURIS RIVER, NORTH DAKOTA

DESIGN MEMORANDUM NO. 3
GENERAL PROJECT DESIGN

APPENDIX E

COORDINATION

APPENDIX E

COORDINATION

TABLE OF CONTENTS

NCDED-T
MEMORANDUM FOR RECORD
SUBJECT: Issue Resolution Conference - Lake Darling, ND

1. References:

a. Director of Civil Works letter, dated 9 March 1982 to Commander, North Central Division; subject, Burlington Dam (Lake Darling) ND project (Inclosure 1).

b. Commander, North Central Division letter, dated 12 April 1982, to Commander, St. Paul District; subject, Lake Darling, ND project (Inclosure 2).

2. On 13 April 1982, the subject conference was held in the St. Paul District Office with OCE, NCD and St. Paul District Office participants in attendance. The conference agenda and attendance roster is attached at Inclosures 3 and 4 respectively.

3. The conference, chaired by Mr. Goodwin, consisted of four basic segments of discussion as follows:

a. Introduction, project overview and District Engineer's comments.

b. Discussion and clarification of OCE/NCD guidance stated in References 1a and 1b.

c. Discussion and resolution of additional issues.

d. Conclusion.

4. Introduction, Project Overview and District Engineer's Comments.

a. Introduction. Mr. Goodwin stated that the purpose of the conference was to (1) review and clarify OCE/NCD guidance stated in References 1a and 1b, and (2) discuss other remaining project issues and develop appropriate guidance for follow up action.

b. Project Overview. Mr. Loss provided a brief project background and overview with an accompanying slide presentation.

c. District Engineer's Comments. Colonel Badger provided the following perception of the project.

(1) The implementation of the Lake Darling project has positive features; it has strong support by an influential congressional delegation from North Dakota, future funding appears to be forthcoming and there is strong local support for the project.

(2) The Corps of Engineers "has the ball in their court" for the implementation of the project.

(3) The various levels within the Corps must have a clear understanding of what is expected of each other in bringing the project to reality.

5. Discussion and Clarification of OCE/NCD Guidance Outlined in References 1a and 1b.

Guidance on the following issues, furnished in References 1a and 1b, were discussed, differences in interpretation were resolved, and there was common agreement on the following points:

a. Point 1. The development of project features will assume no additional flood protection beyond this authorization. It was recognized that justification of a future added increment of flood protection would be difficult since there are few remaining benefits for incremental justification.

b. Point 2. The appropriate interest rate for the project is 5-1/8 percent, since the project is considered to be an integral part of the completed Minot channel project. Accordingly, the application of the a,b,c requirements would be appropriate for the local protection features of the project, and the frozen rate of 5-1/8 percent is appropriate for the justification of separate project features. The District is to proceed on the basis that innovative financing will not apply to the Lake Darling project.

c. Point 3. The development of the project plan will be presented in a General Design Memorandum (GDM). This GDM will include a section on reevaluation of the project which will include a description of the project plan and an explanation of the formulation rationale. This evaluation discussion may be optionally submitted as a separate report. The GDM may make references to the Burlington Dam Phase II GDM and the level of detail presented will assume that a future feature design memorandum (FDM) will be presented on each independent feature. It is recognized that completion and approval of the Velva FDM will precede the completion of the GDM. Also, the hydraulic model study, which is currently scheduled to precede the completion of the GDM, may require an interim meeting with NCD and OCE, prior to study initiation, to discuss the hydrology analysis and conceptual dam design. NCD has approval authority for the GDM and some FDM's. The FDM's for the Lake Darling Dam and any local protection features with interior drainage works require OCE approval. The Velva FDM will not have to present a complete formulation analysis for the entire range of levels of flood protection from 5,000 cfs to Standard Project Flood (SPF). The appropriate level of flood protection should approach the point of not being incrementally justified when evaluated as a second-in-place feature to the Lake Darling Dam raise at 5-1/8 percent interest rates. However, considerations will also be given to (1) the level of protection without modification to Lake Darling Dam, since the Velva levees will most likely be in place first; (2) the safety aspect of the levee height, as related to protection from a catastrophic flood; and (3) a point of discontinuity on a cost curve, where a slightly higher degree of protection will involve excessive costs. A discussion of the above considerations is viewed as an appropriate evaluation for selecting the level of flood protection.

d. Point 4. The downstream urban flood protection measures, which are not incrementally justified, are to be considered as an integral part of the Lake Darling Dam structure and, therefore, can be federally funded up to 5,000 cfs level of protection. All downstream flood protection measures are to be accomplished with local cooperation. This means the local sponsor will be responsible for acquiring lands, easements and right-of-way, as well as for operating and

maintaining the project. This coincides with the policy set out in the letter from the Director of Civil Works, dated 9 March 1982. (The Federal Government is responsible for lands and relocations in the reservoir.) If the local interests desire a level of flood protection higher than the 5,000 cfs reservoir release rate, they will have to fund the incremental higher level of protection.

Regarding the 117 downstream rural residences and the 40,000 acres affected by the 5,000 cfs release, there are essentially three basic options: levees, flood proofing, or evacuation. In all cases, the local sponsor will be responsible for acquiring the necessary interest in the land. The most feasible solution to provide protection from the 5,000 cfs discharge will be federally funded with locals responsible for a,b,c requirements, subject to the Constitution, (which requires just compensation). Any more expensive options desired by either the affected homeowner or the local sponsor may require that the additional funding needed be furnished by the local sponsor. The local cooperation agreement is to provide a requirement to adopt floodplain zoning regulations to prevent additional residences from being built within the 5,000 cfs inundation area. With the above concept, individual owners do not have the option to do nothing.

e. Point 5. The tiered principle for EIS reporting is acceptable.

f. Point 6. The District will provide a written request for a revised completion date for the mitigation report. Submitting the report with the Lake Darling Dam EIS appears appropriate.

6. Discussion and Resolution of Additional Issues.

The following additional issues, primarily involving real estate policy, were discussed and resolved by development of viable options that can be used in working with local interests.

a. Lake Darling Dam Formulation. The formulation of the embankment height and the spillway configuration should consider the reservoir real estate and relocation needs, downstream discharge constraints, fish and wildlife constraints and cost effectiveness. There are essentially three alternatives that should be considered in the evaluation. They are:

(1) A maximum pool level of elevation 1605.

(2) A design pool level of elevation 1605 and induced surcharge storage to elevations higher than this stage, but which would not be worse than existing conditions to upstream real estate.

(3) The most cost-effective design for a controlled design pool at elevation 1605.

The real estate take line for the first two alternatives above is considered to be elevation 1605 plus appropriate freeboard, and the take line for the third alternative is expected to result in a take line at a higher elevation. The operating plan is expected to be similar to that developed for the Burlington Dam plan, with a maximum release of 5,000 cfs and reducing the discharge to 500 cfs during the summer. The dam and spillway cannot be designed to allow the peak flows downstream to exceed the existing condition peak flows for any

flood event up to a PMF. The economic analysis of the project should recognize the cost of upgrading the Lake Darling Dam to meet current dam safety criteria as a project benefit (advanced replacement benefits).

b. Renville County Park. The following points should be considered when developing an acceptable solution to the park situation:

(1) Fee title purchase and removal of the structures are the normally selected solutions by the Corps, but local interests are opposed to this solution.

(2) Some interest in the land below the real estate take line is required; this may be a flowage easement.

(3) Habitable dwellings are not normally allowed to remain on flowage easement areas unless a variance is granted by OCE.

(4) Relocation of the park to another site may be an alternative (although the Bureau of the Budget flagged this proposal in the Burlington Dam authorization).

(5) Construction of a cutoff and protection with a levee may be options.

(6) Purchase of flowage easements, removal of the private structures and allowing limited use during the nonflood season or flood proofing the existing structures may be options.

c. Six-hundred (600) acres north of refuge. Freeboard for wave action, erosion, etc., plus any backwater affect must be taken into consideration when determining the real estate take line for the reservoir. Interest in these lands is expected to be in the form of flowage easements.

d. Break-out points. A solution to this situation may be to acquire the land in fee title and provide a right-of-access to the lake for the owner of adjacent land.

e. McKinney Cemetery. Some points to consider in developing an acceptable solution to the cemetery situation where approximately 50 graves exist below the 1605 elevation are:

(1). Relocation to another site or within the cemetery at higher elevations (the Corps preferred alternative).

(2) If fill is placed over the site, the graves will have to be raised accordingly (not just the grave markers).

(3) With a levee solution, an evaluation of bouyant forces on the graves and the grave markers should be made.

(4) A local preference of permitting the cemetery to remain in its present location without any modification for periodic inundation would require the approval of the Chief of Engineers as a variance.

7. Conclusion.

Key issues, critical to continued progress on this project, were resolved. Agreement on interpretation of OCE/NCD guidance was achieved and viable options on real estate issues were developed for future discussion with local interests. NCD will continue close coordination with the District on project progress, provide additional guidance when necessary, and coordinate appropriate actions with OCE.

4 Incl
as

ZANE M. GOODWIN, P.E., Chief
Engineering Division

RODERICK L. THOMPSON, P.E., Chief,
Project Management Branch
Engineering Division, OCE

MONROE L. LESSER, Chief,
Civil Branch, Acquisition Division
Directorate of Real Estate, OCE

WILLIAM HOLLIDAY, Chief,
Central Branch
Planning Division, OCE

PETER A. FISCHER, P.E., Chief,
Engineering Division
St. Paul District

August 18, 1982

Colonel Edward G. Rapp
District Engineer
U.S. Army Engineer District, St. Paul
Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101

Dear Colonel Rapp:

The purpose of this letter is to indicate the interest of the Ward County Water Resource District in accepting responsibilities as the non-Federal sponsor for the Lake Darling, Souris River, North Dakota, flood control project.

We will work in good faith with the adminstration of the United States in the planning and funding process for the project being evaluated and recommended.

Sincerely,

Arden Haner

Arden Haner
Chairman
Ward County Water Resource District

DECISION MEMORANDUM
FOR
SOURIS RIVER JOINT BOARD

14 Jan 83

SUBJECT - Lake Darling Dam Operating Plan

ISSUE - Selection of best balanced operating plan

DISCUSSION -

a. Variables include minimal release rate for extended period or a fast release rate following flood storage.

b. Options (as shown on inclosure 1) are Plan A, which releases 5,000 cfs with cutback to recession or 500 cfs on 15 May, or Plan B, which releases 5,000 cfs until conservation pool is reached.

c. Plan A appears to favor economic, social, safety and Canadian mitigation factors and is considered to be more reversible.

Plan B appears to favor hydrologic operation, engineering, environmental, and fish and wildlife mitigation factors; however, is not as reversible due to required authorization for mitigation on other operating plans.

d. Experience at Baldhill Dam on Sheyenne River is a good example to avoid Plan B-type operation.

e. Within limits of authorized project, there are only marginal benefits with either operating plan.

RECOMMENDATION - Plan A

Edward G. Rapp

2 Incl

EDWARD G. RAPP
Colonel, Corps of Engineers
Commanding

Approved 15 Jan 83
(Date)

Plan A ✓ modified 1600 cfs o/a 15 May
Plan B

[signature]
ARDEN HANER
Chairman, Ward County Water Resources District

for Souris River Flood Control Joint Board (Provisional)

[handwritten signatures] Kimelly, Glenn Wunderlich, McHenry, Kroeple, Oak Creek WRB, Duane ... (Velva City)

ED-M

Engineering
Project Management

MAY 25 1983

Mr. Arden Haner
Chairman, Ward County
Water Resource Board
Douglas, North Dakota 58735

Dear Mr. Haner:

Our letter of May 4, 1983, addressed the need to identify the local sponsor for the Lake Darling project and to provide a general letter of intent. We are enclosing our currently recommended items of local cooperation for your consideration when preparing the letter of intent. You will note that some of these items vary somewhat from those that we have provided previously.

We have deleted the item which addressed the innovative financing policy requiring a certain percentage of project costs to be a local responsibility. Because the Assistant Secretary of the Army for Civil Works has not established a policy and formula for cost sharing, the traditional statutory requirements will be assumed at this time.

Also, an item has been added addressing the need to "hold and save the United States free from damages" at the reservoir levee areas. This item is needed because it would not be economically feasible to design the reservoir levees (such as at Renville County Park) to provide standard project flood protection. The levees would be designed for the 100-year flood stage; however, larger floods could overtop the levees. Without assurances to protect the Government in the event of overtopping, a real estate interest would have to be acquired on the area protected by the levee.

The letter of intent should indicate acceptance of the enclosed items of local cooperation by the project sponsor. If you have any questions, please call David Loss at (612) 725-5917.

Sincerely,

Peter A. Fischer
Chief, Engineering Division

Enclosure

CF:
Mike Dwyer

PROPOSED LOCAL COOPERATION REQUIREMENTS
LAKE DARLING DAM PROJECT

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction and subsequent maintenance of the project;

b. Hold and save the United States free from damages due to the construction, operation and maintenance of the project except where such damages are due to the fault or negligence of the United States or its contractors;

c. Maintain and operate all of the works for the project after completion in accordance with regulations prescribed by the Secretary of the Army;

d. Accomplish without cost to the United States all necessary changes to buildings, highway bridges (including approaches), streets, dams, sewers, and utilities, as required for construction of the project;

e. Prescribe and enforce regulations to prevent encroachment on downstream channel capacities for regulation of the reservoirs; and, if improved drainage channel capacities and ponding areas for interior drainage are impaired, provide substitute storage capacity of equivalent pumping capacity promptly without cost to the United States;

f. At least annually inform affected interests that the project will not provide complete flood protection;

g. Provide guidance and leadership in preventing unwise future development of the flood plain by use of appropriate flood plain management techniques to reduce flood losses from the Lake Darling damsite downstream to the Canadian border;

h. Adjust all water-rights claims resulting from the construction and operation of the project, and hold and save the United States free from damages due to such claims;

i. Zone land currently in agricultural and/or recreational land use to continue in either of those land use categories after protection is provided by the project;

j. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, approved 2 January 1971, in acquiring lands, easements and rights-of-way for construction and subsequent maintenance of the project and inform affected persons of pertinent benefits, policies and procedures in connection with said act;

k. Comply with Section 601 of Title VI of the Civil Rights Act of 1964 (Public Law 88-352) and Department of Defense Directive 5500.11 issued pursuant thereto and published in Part 300 of Title 32, Code of Federal Regulations, in connection with the construction and subsequent maintenance and operation of the project;

l. Hold and save the United States free from damages in the event the levees in the area upstream of Lake Darling Dam are overtopped.

Items a, c and d pertain only to flood protection measures downstream of the reservoir. Item i pertains only to land protected by the Velva levee feature.

P.O. Box 2599
Bismarck, ND 58502
June 14, 1983

Colonel Edward G. Rapp
Department of the Army
St. Paul District, Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, MN 55101

Dear Colonel Rapp:

On June 6, 1983, the Bottineau County, Renville County, Ward County, McHenry County, and Oak Creek Water Resource Districts decided to enter into an agreement for the creation of the Souris River Joint Water Resource Board. Water resource districts have extensive power and authority to plan, locate, relocate, construct, reconstruct, modify, maintain, repair, and control all dams and water conservation and management devices of every nature, and to regulate and control water for the prevention of floods and flood damages. These authorities are contained in Chapter 61-16.1 of the NDCC. The authority of water resource districts to jointly and cooperatively exercise any power which is authorized an individual water resource district is provided in Section 61-16.1-11 of the NDCC.

The purpose of the joint powers agreement is to control and manage the flooding of the Souris River, through the collective and cooperative efforts of the water resource districts which are parties to the agreement.

As a joint board, we have reviewed the Draft Programmatic Environmental Impact Statement for the Lake Darling Flood Control Project and the Draft Feature Environmental Impact Statement for Velva Flood Control, and we support the project features outlined therein. Due to the unique ability of the Souris River Joint Water Resource Board to work towards comprehensive solutions to the water management and flooding problems of the Souris River, we have agreed to serve as the local sponsor for the Lake Darling project. Therefore, the Souris River Joint Water Resource Board has authorized the transmittal of this letter of intent to indicate to you our support for the project, and our desire to serve as the local project sponsor for the project. We hereby acknowledge our understanding of the traditional local cooperation requirements for a project of this nature, and we are willing and able to sign a local cooperation agreement which complies with Section 221 and which includes the items of local cooperation identified in the letter from your office to me dated May 25, 1983.

Hopefully, the foregoing assurances will satisfy your requirement for a commitment for overall project sponsorship. If you have any questions, please let me know. We look forward to implementation of the Lake Darling project without delay.

Sincerely,

Arden Haner

Arden Haner, Chairman
Souris River Joint Water
Resource Board

AH/Mkj
Copy: Souris River Joint Board
Souris River Joint Board Advisory Members
Vern Fahy
Michael Dwyer

United States Department of the Interior
FISH AND WILDLIFE SERVICE
AREA OFFICE—NORTH DAKOTA
1500 CAPITOL AVENUE
[redacted]
BISMARCK, NORTH DAKOTA 58501

SEP 4 1981

Colonel William W. Badger, District Engineer
St. Paul District, Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, Minnesota 55101

Dear Colonel Badger:

We understand that a bill may be introduced in the U.S. Senate this month to appropriate Fiscal Year 1982 funds for the construction of interim flood protection measures on the Souris River. The bill would appropriate funds for a 4-foot raise of Lake Darling Dam and construction of levees downstream from Lake Darling. The request for interim flood protection measures, in lieu of the authorized Burlington Dam, is a result of a Memorandum of Understanding (MOU) agreed to by supporters and opponents of Burlington Dam to secure a reasonable level of flood protection, pending a comprehensive study of permanent flood control alternatives.

The alternative flood control measures that have been mentioned include investigation of the feasibility of incorporating flood storage in the proposed Rafferty Dam in Saskatchewan and a series of water retention structures in the Des Lacs River Basin. Another proposal that has been advanced is a study of the feasibility of a total water management plan for the Souris Basin which would include effective controls on drainage.

According to the MOU, the investigation of alternative approaches to permanent flood protection will be conducted during the period of construction on the interim features or for 7 years, whichever period is longer. During the period of investigation, reauthorization of Burlington Dam will not be supported by the signatories to the MOU. If the studies conclusively demonstrate that alternative flood control measures, which diminish the negative impacts of Burlington Dam are feasible, the signatories agree to pursue authorization and construction of those alternatives.

Because a bill may be introduced and passed by the current session of Congress to provide funds for interim flood protection measures, and because of requests from representatives of those seeking those measures, the Fish and Wildlife Service is placed in the unusual position of forming conclusions about the impacts of the project before details of construction and operation are known. As you know, our previous evaluation of the raised Lake Darling Dam was based on it being built and operated as part of a two-dam system. We have not, therefore, had the opportunity to assess the impacts that may result from construction of a greatly enlarged spillway or to evaluate a reservoir operation plan involving only Lake Darling.

Assuming that no drastic new plan of operation is developed, we believe our knowledge of potential impacts is sufficient to state that the Service supports the 4-foot raise of Lake Darling and that no separable lands for wildlife mitigation will be required for the interim works of improvement. Although an unquantified acreage of terrestrial habitat will be adversely affected by the raised flood pool, by construction of the dam, and possibly by the removal of gravel, rock and fill from Upper Souris Refuge, these adverse impacts can be largely offset by structural improvements to refuge water control structures, spillways and dams. In addition to the rebuilding of Lake Darling Dam, we recommend that reinforcement and modification of Dams 41, 87 and 96 be accomplished essentially as previously planned. This would include raising Dams 41 and 87, flood proofing all three dikes, rehabilitating the spillways, and replacing the water control structures. These measures would improve water level management in nonflood years and protect the refuge from damage during flood years. Also, if the enlarged spillway encroaches on the boat house, service building and residence in the refuge headquarters area, these facilities must be replaced. A part of any potential wildlife plan would be management by the Service of any lands required for flood control under the terms of a General Plan.

If the downstream levee work proposed as an interim flood protection measure is the same plan we have previously evaluated, we stand by our conclusion that impacts will be slight and that no additional separable mitigation lands would be required. We would appreciate an opportunity to make recommendations to minimize impacts of levee construction at an appropriate time.

This is to apprise you as early as possible of the position of the Service on the major issues surrounding the proposed interim flood control measures. We will welcome the opportunity, as provided by the Fish and Wildlife Coordination Act, to evaluate detailed plans as they are developed and to provide specific recommendations on features needed to reduce damages to wildlife resources and to mitigate those impacts where they are unavoidable. Likewise, we look forward to the opportunity to participate in studies of alternative permanent flood protection measures.

In summary, the Fish and Wildlife Service supports the proposed interim flood protection measures proposed for the Souris River. We believe mitigation of adverse impacts to fish and wildlife resources can be accomplished by structural improvements to Upper Souris Refuge facilities and in part by management of lands that may be required by the Corps of Engineers for flood storage. Furthermore, the Service enthusiastically endorses the comprehensive study of permanent flood control alternatives. We especially support any studies that might lead to basinwide control of drainage.

Sincerely,

Gilbert E. Key

Gilbert E. Key
Area Manager

cc: Governor of North Dakota
Gary Helgeson, Natural Resource Coordinator, North Dakota
ND Game & Fish Dept.
Orlin Hanson, Chairman, Citizens United to Save the Valley, Sherwood, ND
Chester Reiten, Mayor of Minot, ND

United States Department of the Interior
FISH AND WILDLIFE SERVICE

MAILING ADDRESS
Post Office Box 25486
Denver Federal Center
Denver, Colorado 80225

STREET LOCATION
134 Union Blvd.
Lakewood, Colorado 80228

R74

IN REPLY REFER TO
ENV

JAN 13 1983

Colonel Edward G. Rapp
District Engineer
St. Paul District, Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101

Dear Colonel Rapp:

One of the items discussed at the December 15, 1982, coordination meeting between our staffs concerned the alternative operating plans for the proposed 4-foot raise of Lake Darling. This letter is to document the Fish and Wildlife Service's (FWS) preference. Under the operating plan preferred by FWS, the drawdown and storage phases are the same as those proposed by the Corps (see Enclosure 1 for Lake Darling Preflood Drawdown Criteria). The reservoir emptying criteria proposed by FWS is to release the target flows (up to 5,000 cfs) until the conservation pool elevation is reached (Enclosure 2).

It is our view that the detrimental impacts from other operating alternatives far outweigh the limited amount of downstream benefit. If the May 15 cutback plans were implemented, there could exist during the entire summer and at least part of the fall a shortage of flood storage capacity in the reservoir and in the river. This situation would render the valley more vulnerable to flooding from heavy rain storms during this extended time period. Following any of the operating schedules with a May 15 cutback could result in the following detrimental impacts:

1. Habitats above Lake Darling would be impacted rather severely, including marshland and woodland flooding, and increased erosion and siltation. In some flood years, these impacts could be severe enough to result in loss of marsh habitat for the year, and permanent damage to the riparian forest.

2. A large acreage of climax hardwood bottomlands on J. Clark Salyer National Wildlife Refuge (NWR) would be flooded for extended periods of time. This would likely result in permanent loss of much of this community and its associated wildlife.

3. The extended high flow operating plans would result in an inability to manage the marshes at J. Clark Salyer NWR. This inability to manage translates into direct losses of waterfowl production and other shallow marsh species. Nesting islands would suffer accelerated erosion. Public use and other refuge facilities would be adversely affected.

4. Other habitats at J. Clark Salyer NWR would be flooded during much of the growing season in flood years, including a substantial acreage of oxbows and wet meadows, which are leased for haying. Economic and wildlife uses of these lands would be adversely affected.

5. If high flows persisted into the winter, the potential for carp invasion to J. Clark Salyer NWR would be increased.

In summary, we conclude that the least environmentally damaging operating alternative for this project would be that designed to release the target flows (up to 5,000 cfs) until the conservation pool elevation is reached (Enclosure 2). We understand the majority of affected interests along the Souris River also favor this alternative.

Sincerely,

ROBERT H. SHIELDS
Acting Regional Director

Enclosure

cc: Upper Souris NWR
J. Clark Salyer NWR
Environment, Bismarck
ND Game and Fish Dept.

Enclosure 1

– LAKE DARLING PREFLOOD DRAWDOWN CRITERIA

Pool Elevation on 1 March	Predicted 30-Day Flood Volume @ Sherwood in Ac.-Ft.	Peak Target Flow at Minot or Max. Release Rate in cfs (as measured in Minot)	Approximate Pool Elevation During Drawdown Prior to Flood Attainment of Peak Target Flow at Minot*			
			March 15	March 31	April 15	April 30
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1594	0– 50,000	0–1,300	1594	1594	1594	1594
1594	50,000–100,000	1,300–2,000	1594	1594	1594	1594
1594	100,000–150,000	2,000–2,000	1593.3	1592.4	1591.4	1591
1594	150,000–200,000	2,000–2,800	1593.3	1592.4	1591.4	1591
1594	200,000–250,000	2,800–5,000	1593.3	1592.4	1591.4	1591
1594	250,000–Design	5,000–5,000	1593.3	1592.4	1591.4	1591
1593	0– 50,000	0–1,300	Store to 1594 as inflow permits and			
1593	50,000–100,000	1,300–2,000	hold to beginning of flood.			
1593	100,000–150,000	2,000–2,000	1592.2	1591.2	1591	1591
1593	150,000–200,000	2,000–2,800	1592.2	1591.2	1591	1591
1593	200,000–250,000	2,800–5,000	1592.2	1591.2	1591	1591
1593	250,000–Design	5,000–5,000	1592.2	1591.2	1591	1591
1592	0– 50,000	0–1,300	Store to 1594 as inflow permits and			
1592	50,000–100,000	1,300–2,000	hold to beginning of flood.			
1592	100,000–150,000	2,000–2,000	1591.1	1591	1591	1591
1592	150,000–200,000	2,000–2,800	1591.1	1591	1591	1591
1592	200,000–250,000	2,800–5,000	1591.1	1591	1591	1591
1592	250,000–Design	5,000–5,000	1591.1	1591	1591	1591
1591	0– 50,000	0–1,300	Store to 1594 as inflow permits and			
1591	50,000–100,000	1,300–2,000	hold to beginning of flood.			
1591	100,000–150,000	2,000–2,000	1591	1591	1591	1591
1591	150,000–200,000	2,000–2,800	1591	1591	1591	1591
1591	200,000–250,000	2,800–5,000	1591	1591	1591	1591
1591	250,000–Design	5,000–5,000	1591	1591	1591	1591

*NOTE: A release rate of 250 cfs was used in determining approximate pool elevations during drawdown. This release rate is estimated to be the non-damaging discharge during ice cover.

Enclosure 2

RESERVOIR EMPTYING CRITERIA

Predicted 30-Day Flood Volume at Sherwood in Acre-Feet	Peak Target Flow Measured at Minot in cfs	Emptying Schedule.
0 - 50,000	0 - 1,300	Release adjusted to produce a maximum Minot flow equal to target flow. Actual releases made to increase level of Lake Darling to summer conservation pool as soon as possible.
50,000 - 100,000	1,300 - 2,000	Releases adjusted to produce a maximum Minot flow equal to target flow. Actual releases controlled to assure that summer conservation pool is reached in Lake Darling.
100,000 - 150,000	2,000	Releases adjusted to produce a maximum Minot flow equal to target flow. These maximum flows will continue until Lake Darling has been drawn down to summer conservation pool. If the uncontrolled local flow at Minot exceeds the target flow that peak flow, up to 5,000 cfs, will be maintained at Minot until Lake Darling has been drawn down to summer conservation pool.
150,000 - 200,000	2,000 - 2,800	
200,000 - 225,000	2,800 - 3,600	
225,000 - 250,000	3,600 - 5,000	
250,000 - Design	5,000	

DISPOSITION FORM

For use of this form, see AR 340-15, the proponent agency is TAGCEN.

REFERENCE OR OFFICE SYMBOL	SUBJECT
NCSED-M	Meeting with Fish and Wildlife Service at Upper Souris Refuge Headquarters (Lake Darling)

TO	FROM	DATE	CMT 1
Memo for Record	NCSED-M	29 April 1983 Mr. Loss/ew/5917	

1. The subject meeting was held on 27 April 1983. The following people attended:

FWS

Dale Henry	- Refuge Director	- Denver Regional Office
Maurice Wright	- Refuge Manager	- Upper Souris Refuge
Darrold Walls	- Refuge Manager	- J. Clark Salyer Refuge
Vic Hall	- Biologist	- Bismarck Field Office

Corps

Robbin Blackman	- PD-ER
Jeannie Wagner	- PD-ER
David Loss	- ED-M

2. The inclosed list (inclosure 1) of structural improvements at the two refuges was used as a basis for discussion at the meeting Inclosure 2 is the revised list of features as agreed upon at the meeting. The revised lists will be used for the GDM and is understood to represent a possible upper limit of mitigation items. The final justified items will be identified in the mitigation report.

3. In addition to the revised list of structural modifications, the following points were discussed:

a. Mitigation needs in each refuge will be compensated for in that refuge. Other mitigation measures will be distributed in each refuge as determined appropriate by the FWS.

b. Darrold Walls will furnish data on the White Spur and Stone Creek drainage projects for further evaluation of future drainage impacts.

c. The present mitigation analysis will be based on the currently available hydrographs. If the analysis of changed operating conditions for the existing condition hydrographs or future local drainage projects appear to be a basis for a modified mitigation package, it will be evaluated later.

d. Dam 41 embankment will not be raised to elevation 1604 as previously planned, and the only justification for raising the spillway is to provide better access to the low-flow structure. Therefore, the proposed design at Dam 41 will include upgrading the spillway at the present elevation of 1596.5, providing an improved access road from the east, and providing an electric actuator for the gated outlet. Improving the access road will involve upgrading a 2 1/2-mile segment of township road.

DA FORM 1 FEB 62 2496 REPLACES DD FORM 96, WHICH IS OBSOLETE. U S GPO 1979-0-310-981/8129

e. The service roads in the reservoir area include parallel routes on both sides of the valley that are not continuous. These roads are to be upgraded to elevation 1602, which requires raises through some tributary drainage locations. Culverts will be required. Maurice Wright is to furnish a map showing the locations of work needed.

f. The water supply to pond A is to be at 100 cfs. However, if the existing spillway is removed as part of the improvements, the bypass line could be reduced to 50 cfs because there is major seepage loss under the spillway.

g. The FWS indicated no objection when shown a preliminary cross section of the Lake Darling Dam raise with the excess excavated material from the spillway placed on the downstream slope of the dam. They discussed the potential for developing a fishing area on the downstream face as a positive feature of a wide embankment crest. The downstream fishery would be preferable to an upstream fishing dock as a replacement for the spillway fishing area.

h. The upstream boat landings are to be operational at a pool elevation of 1600, which would require the ramps to extend landward to approximately elevation 1602.

i. Mr. Wright will furnish specifications for fencing.

j. Mr. Wright was asked about an agreement that the FWS might have with the Soo Line Railroad Company for riprap replacement on the Greene crossing because the railroad company indicated that the FWS had performed repairs there in 1970. He did not know of any agreements, but said he would check with Irv Rostad, a retired refuge assistant manager.

k. The actuators for the gates are to be electric. One gasoline-driven actuator for each refuge should be provided as a stand-by unit. The FWS estimated the cost of such stand-by unit to be approximately $300.

l. The additional operating capability of an added bay at the outlets in Dam 87 and 96 was questioned. Maurice will discuss the need for the additional bays with Terry Clayton and get back to us.

m. The service roads downstream of Lake Darling Dam in the USNWR are assumed to include 3 miles of roads that would require ditching and surfacing.

n. Because it cannot be definitely shown at this time that carp migration into the United States portion of the Souris will not become more likely, especially considering other proposed drainage projects, it was agreed that costs would remain in the project plan.

o. The FWS agreed that they would be responsible for any additional operating costs, including heaters, for the refuge dams, except Lake Darling Dam.

NCSED-M 29 April 1983

SUBJECT: Meeting with Fish and Wildlife Service at Upper Souris Refuge Headquarters (Lake Darling)

p. The FWS proposed a high priority mitigation feature in place of the land acquisition item on the first list of JCSNWR features. The mitigation item is the construction of approximately 20 potholes ranging in size from 1/2 to 1 acre, 3 to 4 feet deep, and having 1:10 side slopes. The excavated material would be hauled from the area.

q. The service roads and launching sites in the JCSNWR should be estimated assuming that 5 miles of 18-foot roads will be raised approximately 3 feet using soil from adjacent ditch excavation. They should be gravel surfaced and will require 12 - 36 inch Ø culverts.

David C. Loss

2 Incl
as

DAVID C. LOSS
Project Manager

Modifications Required in Upper Souris Refuge
for Operational Revisions

1. Upgrade Dam 41 (upgrade spillway at same elevation, improve access from east, actuator on gate).

2. Raise service roads in reservoir area (elevation 1602).

3. Provide water supply for Pond A (100 cfs).

4. Provide replacement facility for spillway fishing area.

5. Raise boat launch facilities in reservoir (elevation 1600 operating level).

6. Modify fencing for revised boundaries.

7. Provide heaters, actuators, and repaired gates on Dams 87 and 96.

8. Replace outlet from Pond A (if stop log structure affected by toe of Lake Darling Dam).

Incl 2

Mitigation Features in Upper Souris Refuge

1. Provide two low-flow outlets at Pool A and remove spillway (some of this work may be done as operational needs if stop log structure is affected by Lake Darling Dam toe.

2. Upgrade Dam 96 (possibly with two bays).

3. Upgrade Dam 87 (possibly with two bays).

4. Provide bypass at Dam 87 to downstream impoundment.

5. Raise spillway at Dam 87 one (1) foot, rehab dike, and restore marsh.

6. Upgrade Dikes B and C.

7. Upgrade downstream trails.

Modifications Required in J. Clark Salyer Refuge
for Operational Revisions

1. Provide carp control velocity barrier for large flows and electric weir for low flows.

2. Provide heaters, actuators, and repaired gates on all five structures.

3. Raise service roads, senic trails, boat and canoe launch and exit sites.

Mitigation Features in J. Clark Salyer Refuge

1. Construct potholes in wet meadow areas.
2. Upgrade Dam 320 with spillway and top of gates 2 feet higher.
3. Upgrade Dam 326 with spillway and top of gates 2 feet higher.
4. Upgrade Dam 332 with spillway and top of gates 2 feet higher.
5. Upgrade Dam 341 with spillway and top of gates 2 feet higher.
6. Upgrade Dam 357.
7. Add low-flow structures at Dam 320 for improved circulation.
8. Add low-flow structure at Dam 326 for improved circulation.

United States Department of the Interior
FISH AND WILDLIFE SERVICE
[redacted]—NORTH DAKOTA
1500 CAPITOL AVENUE
BISMARCK, NORTH DAKOTA 58501

JUN - 7 1983

Colonel Edward G. Rapp, District Engineer
St. Paul District, Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, Minnesota 55101

Re: Lake Darling Flood Control Project

Dear Colonel Rapp:

This letter provides preliminary planning aid information for Items 1, 2, 3 and 7 of the Scope of Work for Fiscal Year 1983. Our purpose is to assist you in preparing the Lake Darling Phase I General Design Memorandum. These items contain the study assumptions and preliminary data defining and analyzing the present and predicted future terrestrial wildlife habitat conditions. Marsh habitats, natural and developed, are included. Lacustrine and riverine fish habitats have been addressed in a previous planning aid letter (December 29, 1982). Their recreational use and harvest will be described following completion of the spring and summer 1983 creel and use survey. A draft Fish and Wildlife Coordination Act (FWCA) report will be prepared for the Lake Darling site-specific Environmental Impact Statement and the Feature Design Memorandum.

Endangered species that may be found in the project area are: bald eagle, whooping crane and peregrine falcon. Their occurrence would be during migration periods, using area habitats for resting and feeding. Your site-specific Lake Darling EIS should include a supplement to the biological assessment which addresses these species and provides conclusions as to whether or not the project is likely to affect them.

A basic assumption for this study was that habitat values, land uses and habitat acres by type have not changed significantly since the Burlington Study. Land uses in the direct project area of influence, the riverine corridor, were projected to remain essentially unchanged in the future without project analysis. Significant changes would be unlikely, given the continued probability of flooding.

For the entire watershed area, continued conversion of pothole wetlands, grasslands and woodlands to cultivated areas is anticipated. The principal effect of such conversion upon the Souris River System comes from wetland drainage into the tributary streams and the mainstem.

An estimate of total wetland drainage to 1980 in the five major counties (Bottineau, Renville, Ward, Rolette and McHenry) was made based on wet soils mapped by the Soil Conservation Service. The average for these counties was 30.9 percent of the wet acres drained. If we assume this represents 100 years of drainage, a projection of an equal amount in the next 100 years (life of project) would be an additional 209,000 acres drained. These five counties are

only a rough approximation of the watershed area for North Dakota. The data is presented for comparison. A second estimate of drainage to 1980 (this one for the entire North Dakota portion of the Souris River Basin), by the Souris-Red-Rainy River Basin Commission was about 222,000 acres. A recent study of water storage capacity of natural wetland depressions in the Devils Lake Basin (Ludden, et al.) found an average depth of 1.1 feet of storage for a 25-year frequency runoff. Using this figure, projected future without project drainage only in North Dakota will add an additional 220,000 to 230,000 acre-feet of water to the Souris during a 25-year frequency event, assuming 95 percent ultimately entering the Souris Basin.

It is our view that this past and projected wetland drainage in the United States and Canada has already and will continue to result in increasing frequency of both small (less than 275,000 acre-feet, 30-day volume) and large floods (greater than 275,000 acre-feet, 30-day volume). That this is actually occurring seems borne out by the record of seven flood events from 1969 to 1979. Although wetland drainage is not directly project related, the perception of increased flood control can serve to stimulate additional drainage in the absence of effective constraints. The large amount of drainage also has and will continue to degrade all the aquatic and wetland systems along the Souris. The continued degradation of the large marshes of J. Clark Salyer from drainage related sediments, nutrients and other pollutants is projected to significantly reduce their future habitat values.

Impacts resulting from your recommended operating plan will be emphasized. The Fish and Wildlife Service (FWS) preferred operating plan has been identified (Acting Regional Director's letter of January 13, 1983) and will not be further discussed here. The project operating plan will apply when flood events are predicted or in progress. Maximum flexibility will be retained to manage reservoir levels and releases to achieve Service management objectives each flood year during preflood and flood recession operations, within the necessary and agreed upon constraints imposed by the flood management function. The degree of flexibility will be defined during detailed studies. Direct construction impacts have not been quantified except for the Velva phase of the project. Project impacts on fish and wildlife resources should be defined by November 1983, so that specific conservation measures can be described, justified and recommended in the draft FWCA report.

During the Burlington Reservoir analysis, a large data collecting effort was made. The Habitat Evaluation Procedures were used to evaluate existing habitats and project impacts. It was decided to adapt this existing data to the Lake Darling Study to the extent feasible, for several reasons. Principally, they included considerations of time and money available as well as previously spent, and a judgement of continued relevancy.

For purposes of project analysis, terrestrial habitats were aggregated into four types: (1) hardwood (primarily riverine forest); (2) marsh (includes natural and impounded flood-plain palustrine wetlands); (3) grassland (native and introduced); and (4) agricultural, or cropped land. These interrelated habitats include the single-purpose dedicated wildlife lands on Upper Souris and J. Clark Salyer National Wildlife Refuges, and the private lands along the

river in between, which are devoted to agricultural, urban and residential uses. The refuge lands correspond to Resource Category 2 of the U.S. Fish and Wildlife Service Mitigation Policy. The Designation Criteria are: "Habitat to be impacted is of high value for evaluation species and is relatively scarce or becoming scarce on a national basis". The Mitigation Goal is: "No net loss of in-kind habitat value". The remaining habitats in private lands fall under Resource Category 3 - "High to medium value for evaluation species and is relatively abundant on a national basis," with a goal of "no net loss of habitat value while minimizing loss of in-kind habitat value."

Species evaluated included the following:

Marsh	Hardwoods	Grassland	Cultivated Land
White-tailed Deer	White-tailed Deer	White-tailed Deer	White-tailed Deer
Red Fox	Raccoon	White-tailed Jackrabbit	White-tailed Jackrabbit
Mink	Beaver	Badger	Red Fox
Raccoon	Mink	Red Fox	Skunk
Pheasant	Pheasant	Sharp-tailed Grouse	Gray Partridge
Blue-winged Teal	Wood Duck	Blue-winged Teal	Mallard
Avocet	Great Blue Heron	Willet	Franklin Gull
Canvasback	Chickadee	Meadowlark	Horned Lark
Canada Goose			

Species requirements were evaluated for year-round use, where applicable, and the results combined into an average habitat type unit value on a zero to 100 scale. An assumption inherent in these procedures is that other species are adequately represented. If information becomes available to the contrary, additional evaluations should be made. Two hundred eighty-four species of birds and 49 species of mammals have been observed on J. Clark Salyer NWR.

Where habitat types exhibited significant variations in value, as in the different marsh types, the sampling design was made to evaluate these differences. Mean base condition habitat values are: hardwood forest, 71 (all segments); wetlands, 43 (segments 3-5), 52.5 (segment 6), 68 (segments 1, 2 and 7); grasslands, 54 (segments 1-6), 68 (segment 7); and cultivated land, 35 (all segments). Planning segments are: 1, Canada to upper Lake Darling; 2, Lake Darling; 3, Lake Darling to Baker Bridge; 4, Baker Bridge to Burlington; 5, Burlington to Logan; 6, Logan to J. Clark Salyer NWR; 7, J. Clark Salyer NWR.

Impacts related to flooding of the four habitat types during the growing season were determined for the future without and the with project conditions. Future drainage and irrigation flows were not included. Above Lake Darling, acres of each type were estimated at 1-foot contour intervals. Hydrographs provided inundation durations for each contour. The mid-point of each contour was used to represent conditions for the entire interval. Five recent historical flood events were analyzed (1970, 1974, 1975, 1976 and 1979). Damage frequency curves provided estimates of habitat value changes due to storage in the reservoir (modified condition minus existing condition) for each event. Summary tables follow:

Segments 1 & 2 Habitat Type	Acres (1596-1605)	H.U. Value	% H.U. Change Due To Project 1970	1974	1975	1976	1979
Wetland	1779	76,497	-9.3	4.6	-23.5	-29.3	-33.5
Woodland	415	29,465	0	0	-0.2	-1.7	-0.3
Grassland	1064	57,456	-3.0	1.6	-1.1	-22.3	-17.2
Cultivated Land	445	15,575	0	0.06	-1.4	-26.4	-3.5
Total	3703	178,993	-4.9	2.5	-13.8	-22.3	-20.2

Segments 1 & 2 Habitat Type	1970	H.U. Change Due to Project 1974	1975	1976	1979
WetLand	-7,138	3,548	-17,998	-22,447	-25,646
Woodland	0	0	-63	-515	-77
Grassland	-1,717	924	-6,357	-12,803	-9,864
Cultivated Land	0	9	-222	-4,112	-544
Total	-8,855	4,481	-24,640	-39,877	-36,131

Below Lake Darling Dam, flooding impacts were estimated in similar fashion for habitats below the elevations inundated at river flows of 2800 cfs and 5000 cfs. It is known that impacts occur at lower river flows; these have not been quantified. Discharge hydrographs used to represent river segments are: Foxholm gauge - Lake Darling to Burlington; Minot - Burlington to Logan; Verendrye - Logan to J. Clark Salyer NWR; Bantry plus Westhope divided by two - J. Clark Salyer NWR. Summary tables follow:

Segments 3-7 Habitat Type	Acres (a)	(b)	H.U. Values (a)	(b)
Wetland	26,400	7,567	1,564,476	444,652
Woodland	3,495	6,509	248,109	462,104
Grassland	3,024	4,270	178,644	245,016
Cultivated Land	3,800	4,446	133,000	155,610
Total	36,719	22,792	2,124,229	1,307,382

(a) = 2800 cfs flow elevation
(b) = 5000 cfs minus 2800 cfs flow elevation

Segments 3-7 Habitat Type	% H.U. Change Due To Project 1970 (a)	1970 (b)	1974 (a)	1974 (b)	1975 (a)	1975 (b)	1976 (a)	1976 (b)	1979 (a)	1979 (b)
Wetland	1.6	0	-1.2	0	4.9	2.4	-12.1	-17.0	-1.1	2.9
Woodland	0.6	0	0	-.09	0.8	0.1	-8.6	-1.3	0.1	.9
Grassland	6.1	0	-1.9	-.02	8.6	3.3	-12.6	-35.9	-2.9	3.2
Cultivated Land	13.9	0	-4.3	-1.00	7.1	5.0	-0.2	-36.3	-1.8	4.7
Total	2.7	0	-1.3	-.2	4.9	2.0	-11.0	-17.3	-1.1	2.5

Segments 3-7 Habitat Type	H.U. Change Due To Project 1970 (a)	1970 (b)	1974 (a)	1974 (b)	1975 (a)	1975 (b)
Wetland	25,875	0	-18,329	0	77,416	10,900
Woodland	1,455	0	0	-412	2,029	411
Grassland	10,941	0	-3,445	-2,382	15,309	8,076
Cultivated Land	18,523	0	-5,721	-42	9,481	7,677
Total	56,794	0	-27,495	-2,836	104,235	27,064

Segments 3-7 Habitat Type	H.U. Change Due To Project 1976 (a)	1976 (b)	1979 (a)	1979 (b)
Wetland	-189,132	-75,839	-16,287	13,044
Woodland	-21,390	-5,901	130	4,318
Grassland	-22,583	-87,934	-3,252	7,912
Cultivated Land	-294	-56,436	-4,051	7,402
Total	-233,399	-226,110	-23,460	32,676

(a) = 2800 cfs
(b) = 5000 cfs minus 2800 cfs

The habitat value changes from these representative events will be averaged over the life of the project to arrive at an annualized impact estimate. Other project impacts will be quantified to the extent possible and narratively described in the FWCA report. These include direct construction impacts, increased erosion, operational impacts to management of the two NWR's, possible effects on carp invasion, and other effects to the habitats and wildlife of J. Clark Salyer NWR from altered flow regimes.

Additional information needs from the Corps will include site-specific locations, acreages and cover types of all areas to be disturbed by construction. Comparative flow data (with and without project) close to the Wawanesa Dam in Manitoba is needed to analyze potential carp movements. Channel capacity information through J. Clark Salyer NWR is needed to determine operational effects of the altered flows on management of the marshes. Estimates of changes in flows due to projected drainage are needed in order to make informed judgements as to total effects on operations of the NWR's. Timing of these new drainage flows in relation to the altered flows from the project is an important related information need.

Structural measures to mitigate unavoidable project impacts to habitat values and to Refuge operations will be implemented on the two Souris River National Wildlife Refuges in order to avoid the acquisition of separable lands, in accordance with prior commitments. The location and extent of these measures will be determined during the site-specific analysis. A preliminary listing of recommended measures has been developed for each refuge (April 29, 1983, Memo for Record).

We trust this information will be helpful. Any questions or additional requests should be directed to Stan Zschomler (FTS: 783-4481) or Vic Hall (FTS: 783-4491).

Sincerely,

M. S. Zschomler

M. S. Zschomler
Field Supervisor-Habitat Resources

LMED

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